MECHANICS' MAGAZINE,

AND

JOURNAL OF THE MECHANICS' INSTITUTE.

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NEW ARRANGEMENT.—I take pleasure in announcing to the readers of my periodicals that I have taken as a partner, in the business pertaining to them, Mr. GEORGE C. SCHAEFFER, a gentleman of education and a practical engineer.

Mr. Schaeffer will hereafter have the principal charge of the editorial department of the Journal and Mechanics' Magazine—in the discharge of which duties he has for several months past taken an active part—and, as we have reason to believe, much to the satisfaction of our readers and patrons.

With our united efforts we hope to render the periodicals worthy of a more extensive circulation.

D. K. MINOR.

New-York, July 2nd, 1836.

The undersigned has the pleasure of announcing to his friends and to the readers of the Rail-Road Journal and Mechanics' Magazine, that he has become joint proprietor and editor with Mr. D. K. MINOR, who has conducted these journals since their commencement.

In making this announcement the undersigned begs leave to waive the formality of making the usual protestations and claims to favor further than to state that the perseverance and zeal with which these journals have heretofore been conducted are guaranteed to them on the part of Mr. MINOR—while he hopes by his own endeavors to add to their usefulness, his connexion with them for the last six months having already introduced him to the routine of business.

His family circumstances being such as to forbid the pursuit of the profession out of the city, will not prevent him from continuing his favorite studies to the interest and benefit of others.

Should he succeed his most earnest desires will be gratified.

GEORGE C. SCHAEFFER.

July 1st, 1836.

Applications of Chemistry to the Useful Arts, being the substance of a Course of Lectures delivered in Columbia College, New-York, by James Renwick, Professor of Natural Experimental Philosophy and Chemistry.

V.

APPLICATIONS OF HYDROGEN, CARBON, AND THEIR COMPOUDS.

1. AEROSTATION.

The only direct use to which gaseous hydrogen is put, is to the filling of balloons. The hydrogen for this purpose is prepared in the mode usually practised in chemical laboratories but on a larger scale. The substances employed are water, clean iron filings, and sulphuric acid. The apparatus is composed of a number of barrels which are arranged in the circumference of a circle. In each of these, iron filings is introduced to the depth of a few inches, and the barrel is then headed up. Through the head of each barrel a leaden pipe is introduced which reaches nearly to the bottom of the barrel and is formed into a funnel on the outside of the cask. This serves for the introduction of the water and sulphuric acid. Another leaden pipe is passed through the head of each barrel without entering beneath its lower surface. These pipes serve to convey the gas generated in each barrel to a common reservoir, placed in the centre of the circle around which they are arranged. This reservoir is of the character of the chemical apparatus

called a gasometer. It is formed of two large tubs, one of which is inverted within the other. The space between them, as well as the inner tub, is filled with water, the air being allowed to escape from the latter by a tube adapted to its head and furnished with a stop-cock. As soon as this tub is filled with water the stop-cock is closed.

The tubes which convey the gas are passed over the edge of the outer tub or through its staves, and their open ends pass beneath the cavity of the inner tub. The gas therefore enters it, and rising to the surface of the water tends to buoy it up, which action is aided by a counterpoise until the balloon is ready to receive it.

Balloons are bags of a spherical or sphersidal form, made of gores of silk, coated with a varnish which renders it imperrious to air. The best for this purpose is made of caoutchouc. Each of the gores is prolonged into a rectangular strip, and these, when sewed together, form a long cylindric tube. The air having been forced from the balloon by compressing it, this tube is tied to that which is adapted to the inverted barrel, the counterpoise being removed, and the pressure, if necessary, aided by loading the gasometer with weights, the contained gas, with that which is subsequently generated in the barrels, is forced into the balloon until it is completely inflated.

Hydrogen gas having not more than $\frac{1}{13}$th of the density of atmospheric air, the joint weight of a large balloon and the gas which it contains, is far less than an equal bulk of atmospheric air, and it will not only rise itself but will carry with it a considerable additional weight. In order to attatch a weight to it, a net work is formed of cords in such manner as to embrace the upper half of the inflated balloon, and from its equator, straight cords proceed, to which a car is tied. The balloon must be of such size as not only to carry up the persons who are to mount, with their necessary equipment, but also a considerable quantity of ballast. This is in the form of sand tied up in canvass bags. The object of this combined with a valve in the top of the balloon, is to enable the aeronaut to ascend or descend at pleasure as long as the ballast and the gas in the balloon are not wholly expended.

This valve is placed on the top of the balloon and is thus constructed: the gores, instead of meeting in a point, are united upon a ring of whalebone, and thus leave a circular opening; to this a circular shutter of silk, spread upon a similar ring, is adapted by a hinge; two cords proceed from this, over the net work, in opposite directions to the car; by one of these the valve can be opened, and by the other, closed.

Then the balloon is released by cutting cords which held it down, the tube which proceeds from its lower point, and is long enough to reach the car, is left open, in order that the gas in the balloon may be at liberty to escape as it tends to expand itself, in consequence of its reaching regions in the atmosphere less dense then those nearer the surface of the earth. Although the escape of this gas renders the balloon somewhat lighter, it must finally reach a position where its weight is exactly the same as that of an equal bulk of the surrounding air, and must cease to ascend. A farther height may be attained by throwing out ballast. This is done by opening the bags in which it is contained.

When it is wished to descend, the valve in the top of the balloon is opened until the collapse caused by the escape of the gas renders the balloon heavier than an equal bulk of the surrounding medium, and the force which causes the descent will be an increasing one, as the collapse is increased by the increasing pressure of the denser air. It may therefore be necessary to check it by the discharge of ballast, and by doing this in sufficient quantity, the balloon may be rendered stationary or caused to ascend again. In the latter case it is no longer necessary to allow the gas to escape by the tube beneath, which is therefore closed by knotting it.

A balloon has no other capacity of being directed except in ascent and descent. No power has yet been discovered, which can be called into action, of sufficient intensity to propel a balloon through the air, and make it move in a direction contrary to the currents of wind, and which shall be produced by apparatus sufficiently light to be carried up by a balloon.

USES AND PURIFICATION OF WATER.

Water as found in nature is never ab-

solutely pure. Even when it contains no solid matter, either in solution or mechanically mixed, it is charged with gases. The most important of these are carbonic acid and oxygen. These however, so far from being injurious, are absolutely necessary to render water palatable, and probably increase its usefulness in the animal economy. Water which falls in cities where coal is used as a fuel, contains sulphurous acid gas in solution, which gives it a disagreeable taste. This may be readily separated by heating it to the boiling point; as,however,the othus gases will also be driven off, water ther purified must be exposed to the air for some time, in order that it may again absorb oxygen and carbonic acid. The water of rivers is often turbid, in consequence of their carrying with them earthy matter in a state of minute division, it may also contain animal and vegetable matter, or even living animalculæ. Such organic matter renders it unwholsome. The earthy and heavier organic matter may be separated by placing the water in tanks and reservoirs where it may remain at rest, and the clear fluid may be drawn off, but in this way living animals and lighter substances will still remain. It is therefore better to purify it by filtration. In order to deprive it of all disagreeable taste or smell, a part of the filter should be composed of charcoal. By long use, the charcoal will finally become so charged with the offensive matter that it will cease to act. The filter must then be opened and the charcoal replaced by another portion of the same substance, or the old charcoal purified by heat.

The same property of charcoal may be applied to the purification and preservation of water in ships. For the first purpose it is only necessary to mix thoroughly with the water in the casks a few ounces of powdered charcoal; for the latter the casks may be charred within. The purification of water from insoluble matter by filtering is performed by nature on a large scale within the crust of the earth, and that which issues from springs, and is found in wells is usually purified; but it may thus receive soluble impurities, although there are unquestionably some cases where the natural filter has the property of decomposing and retaining the soluble matter. Thus, on islands which are mere sandbeaches, fresh water may often be found by digging, which can have no other source than the neighboring water of the ocean, but this natural process has not been imitated by art.

The mere separation of insoluble matter from water has sometimes been effected on a large scale by taking advantage of natural circumstances. Thus at Glasgow, instead of pumping water from the River Clyde, tunnels of brick laid in sand are sunk in the gravelly bank of the river; through this water filters, and is drawn from the tunnels by a steam engine. At Toulouse, the reservoir which supplies the city is a basin dug in a gravelly bank, and separated from the river by a narrow dyke, through which the water passes perfectly clear. This reservoir has another valuable quality which we cannot avoid mentioning. The lower part of it is filled with large boulders, on these smaller water worn stones are laid; these are succeeded in turn by gravel, and the gravel by sand. The water which occupies the spaces between the stones is thus maintained throughout the year at an uniform temperature, and is neither affected by the frost of winter, or the scorching heats of summer. This temperature too, which is that of native springs, is such as causes the water to retain the greatest quantity of the gases which render it palatable.

Water which is conveyed great distances in pipes, or is precipitated in falls, loses these gases and will not regain them until exposed to the air. A remarkable instance of the last sort occurs at the Falls of Niagara, where the water above the fall is agreeable, and in the pool below as nauseous as that which has been boiled. The same action has even been applied to procure air separated from falling water, to be used in the manner of that forced from a bellows.

Water which comes from springs in the vicinity of the sea or its arms is often impregnated with marine salt. It is then said to be brackish, and for this no remedy has yet been propsed except the costly one of distellation. That from inland springs often holds in solution carbonate of lime by excess of acid, and sulphate of lime. These give the water the character called *hard*, rendering it unfit for the solution of soap, for making vegetable extracts, and for being used in the arts of bleaching and

dyeing. It is also less wholesome as a drink, and, except to persons whose taste has become vitiated, disagreeable.

Nature has provided a slow but sure remedy for this defect. On exposure to the air the excess of carbonic acid which holds the carbonate of lime in solution, is dissipated, and that earthy salt perciptated. If on the other hand sulphate of lime be contained in the water, the superior affinity of that earth for carbonic acid will cause it to attract that acid from the atmosphere, by which this insoluble carbonate will be formed. Thus the water of stagnant ponds, even in countries where calcareous matter abounds, may be well adapted to manufacturing purposes. Such water is however unwholesome, as it undergoes decomposition from the presence of putrescent vegetable matter. But when large rivers flow for a great extent, with a regular and steady course, these chemical changes take place without the corresponding inconvenience arising, and in addition by an action not yet explained, all animal and vegetable matter is rendered insolubie. For this reason the waters of the Nile, the Ganges, and the Mississippi have a well founded reputation for their delicious taste. Even the water of rivers which receive every species of offensive animal and vegetable matter, is, when filtered, almost perfectly pure.

We learn from this, that in supplying cities with water, the true plan is to bring it so far as possible in channels formed like a canal in the natural earth. Channels of masonry are of all the most to be avoided, as the water cannot fail to be contaminated with calcareous matter which will render it unfit for use in any of the chemical arts. The antients did not feel this objection to the use of aqueducts of masonry, partly because they had not reached that advance in the chemical arts, which now makes their practice almost a necessary of life, but more particularly from the very superior quality of their masonry, which was so accurately jointed as hardly to admit the edge of a knife. This perfectiou is not beyond the reach of modern art, but would involve an expense which would not be submitted to.

When water holds calcarous matter in solution, the lime combines with certain acids which exist in all soap, and form with that earth an insoluble compound, which is lighter than water and floats at its surface. The sulphate of lime, which is most frequent, may be decomposed by the salts of ammonia and hence the use of putrescent urine in the art of bleaching.

As this sulphate has the property of combining with vegetable matters and rendering them insoluble in water, water may be rendered soft by boiling in it for a long time some muculagincus vegetables. A more speedy method of rendering hard water soft is as follows :

To purify 100 gallons of water; dissolve six pounds of pearlash, or subcarbonate of soda in a gallon of soft water, boil the solution, when it boils add two ounces of soap cut into small pieces, and stir the boiling liquid until the whole of the soap is dissolved. When this solution is added to the water to be purified, the soap and sulphate of lime mutually decompose each other, the insoluble compound of the acids of the soap with the lime rises and coagulates at the surface, whence it may be sktmmed off.

The sulphate of lime may be more slowly decomposed, by adding a small quantity of carbonate of soda or potash. The acid of this will finally convert the lime into carbonate, which will be precipitated when the excess of acid is expelled. The mode which immediately preceeds, is however, more certain and rapid, and will fit the water for every use in the arts. This is the mode which was referred to in speaking of the bleaching of wool as capable of superceding the offensive matter which is now in use.

Water is most extensively used in preparation of our food, and the proper application of it to this purpose is by no means so simple as it might at first appear. The fibrous flesh of animals is made up of two distinct substances, albumen and gelatine. The former is insoluble in water, and coagulates at the temperature of boiling; the latter is slowly soluble in cold, and more rapidly in boiling water, by which it is previously softened. Albumem exists nearly pure in the white of an egg, gelatine when separated from other matter becomes glue.

When meat is to be cooked by boiling, if it be suddenly exposed to the boiling temperature, the albumen coagulates, and forming a hard coat, protects the gelatine from the action of the water, and although by long continued boiling the latter may be

dissolved, the meat will remain in the form of tough stringy fibres. But if it be slowly raised to the boiling heat, the albumen retains its viscid liquid form until the gelatine is softened and partially dissolved; part of the former also separates and rises to the surface of the fluid whence it may be skimmed off.

It is the solution of the gelatine in water, with a part of the liquid matter of the meat which forms the broth which is the basis of soup.

It will be easily seen from what has been stated, that sudden heat and rapid boiling will render the meat tough, or if continued until it be tender, stringy and tasteless. On the other hand, if gradually heated to the boiling temperature without being ever permitted to boil rapidly, the broth will be more readily charged with gelatine, the meat will be tender and full of its original juices.

It is to the proper application of these principles that the great superiority of French over the English and American cookery is mainly to be attributed, for the broth is not only used by the French in the form of soup but is the vehicle of all their sauces, and the meat whence the soup is prepared, instead of being useless as with us, is the most important of their dishes.

The fat of animals is rendered soluble in water by vegetable matters, and this furnishes an important addition to the means of preparing food. Vegetables fried in butter or fat, and boiled in water, furnish a nourishing and palatable liquid, the *soupe maigre* of Catholic countries. The bones of animals contain large quantities of gelatine, but this is so intimately mixed with an insoluble substance (the phosphate of lime,) that it cannot be separated, except from the mere surface, by water at the ordinary temperature of boiling. Water, however, heated in close vessels to a higher temperature, acquires the power of separating gelatine even from bones. For this purpose, an instrument was invented about 150 years since, by Papin, and called by him the digester. It is a strong vessel of copper, to the mouth of which a circular lid is close fitted by grinding. The vessel stands in in an iron frame having four feet. To the top of these feet a cross of iron, which rests upon the lid, is fastened by screws, and thus the lid is prevented from rising when the first steam is generated within. To complete the arrangement, a safety valve is provided, by the weight of which the pressure of the steam within, and consequent temperature of the water is regulated.

The arrangement for closing the lid of Papin's Digester is too complicated for domestic use. In order to simplify this part, the digester has been modified into the Autoclave. The mouth of this is of an oval form; the shape of the lid is the same, but larger in each of its dimensions. In consequence of both having this figure, the lid may be passed into the vessel and turned around within it, until its longer axis is in the same direction as that of the mouth. In this situation, the first steam that is generated presses the lid close against the vessel, and effectually closes the mouth.

The presence of sulphate of lime renders vegetable matter insoluble in water. Hence green vegetables can only be well cooked, and appear of a good color, in soft water. The latter effect may, however, be attained even with hard water, by adding a small quantity of pearlash to decompose the sulphate of lime.

MANUFACTURE OF CHARCOAL.

Rationale.—When wood is burnt in the open air, under favourable circumstances, as a considerable part of it is either inflamable or volatile, it is dispersed in the process of combustion. The residue is earthy in appearance, and is known by the name of ashes. The quantity of ashes given by different woods, and by different parts of the same tree, vary very materially. Thus the wood of the linden yields eight times as much ashes as the wood of the pine, and bark from 15 to 30 times as much as the wood within. The linden seems to yield the largest quantity of ashes, which is as much as much as five per cent; oak yields about 2½ per cent; and pine eight tenths per cent. The character of these ashes varies in different kinds of wood, but the substances which are almost always found, are the cabonate of lime and magnesia; phosphate of lime; chloride of potassium, and the sulphate and carbonate of potassa; and silicia, either pure or combined with potassa and lime.

By distillation and heat in close vessels, and condensing the volatile parts, the whole of the matter of the wood may be collected. This is now found to consist of a black

mass, retaining the figure and structure of the wood, and known by the name of charcoal, composed of carbon, and the earthy and saline matter mentioned as found in ashes; water; acetic acid held in the water; tar, partly unmixed, and parly dissolved in the water by the action of the acetic acid; with carbonated hodrogen, carbonic oxide and carbonic acid. At the temperature of 340° Fahr. the quantity of solid matter left is nearly double that left at a red heat, and if exposed suddenly to a heat above redness, the quantity of charcoal left, is diminished. The charcoal is itself a product of sufficient value to be sought for to the exclusion of the rest; at other times the decomposition of wood is effected principally for the sake of the acetic acid; the carbonated hydrogen has in some few cases been collected and applied to the purpose of illumination, and when this is the case the tar is also saved.

Manufacture.—The most perfect mode of manufacturing charcoal, is that which corresponds most nearly with the distillation referred to in the preceding section. Wood is introduced into iron cylinders, which are closed, and placed in a heated furnace.—The action is continued as long as any gaseous or volatile matter appears. The cylinder is then removed, and replaced by another also charged with wood. As the gas which is evolved is principally of an inflamable character, it is, after the condensable substances have been separated in a proper refrigerator, carried by a pipe to the furnace, where it is inflamed by the burning fuel, and by the heat of its combusiion, aids in the distillation of the remainder of the wood. This method is employed in the manufacture of charcoal for gunpowder.—In this process, it has been found that dry wood yields 28 per cent. of charcoal, and requires 12½ per cent. of the same wood, used as fuel, to effect its decomposition.

That part of the volatile matter which consists of water holding acetic acid, and tar in solution, goes by the name of pyrolignous acid. This process is sometimes conducted principally in reference to this product, which may be used in the preparation of vinegar, and as a source of pure acetic acid.

The apparatus used in this method is too costly to permit it to be employed in making the great quantities of charcoal which are required in various chemical and mechanical arts, and for domestic purposes. In these cases, recourse is had to the simple and ancient mode of carbonising the wood, in what are usually styled *coal-pits.*

The wood which is to be converted into charcoal, is cut to the usual length of cord wood, say about four feet. A floor is first formed by laying logs radiating from a centre, with an interval of a few inches between them, and filling the sectors of the circle included between them with other logs. At the centre of this circle, a stake is set up vertically, to the top of which two short pieces, crossing each other, are adjusted. Four logs are placed on end, leaning against the stake and supported by the cross. Around these, other logs are placed leaning against them, thus forming a truncated cone resting on the horizontal layer. If the quantity of wood permit, a second and a third range of logs are piled up in the same manner; the rule to be observed, being that the height of the truncated cone shall be about half the diameter of the base. The heap being completed, the outside is covered with small wood, on which are laid twigs and branches. Upon these, a layer of earth, from 4 to 6 inches thick, is placed, covering the whole heap, except a few openings, one of which is in the middle of the top, and others correspond to the radiating passages in the horizontal layer.

The pit being thus finished, it may be set on fire either by pushing burning brands to the centre of the base through one of the horizontal passages; or by drawing out the central stake of the upper layer, and dropping in burning fuel.

A thick smoke will first ooze through the hole at the top of the heap, which will be followed, after a time, by flame. As soon as flame appears, this hole is closed by laying a sod over it. It now becomes necessary to pay particular attention to the regulation of the combustion, by closing and opening the remaining holes, in proportion to the energy of the combustion. If it be too rapid, too large a portion of the charcoal will be consumed; if too slow, the logs will be only partially charred, leaving what are called brands. In addition to the holes already left, it may be neeessary to open others at points where the combustion is too slow, and to stop up crevices which may be formed by the cracking of the earthen covering. A regular and pro-

per action is marked by smoke flowing slowly and in equal quantity from all the openings but that at the top, where the greater rapidity of the current causes a larger quantity of smoke to make its way from under the sod laid upon it. When the outer logs of the pile have been reached by the fire, which will be shown by the outside appearing of a dull red heat at night, the process is completed; all the openings mus then be carefully stopped, and a second layer of earth applied to the whole surface. After a few hours, these coats of earth are removed, and replaced by a third, which must be so applied as to prevent all access of external air.

In a pit of a single layer, the whole process is finished on the fourth day, and the charcoal fit to be drawn. In the largest heaps, it may not be finished for from 15 to 30 days.

This process would be perfect, were no more wood burnt away than is sufficient to drive off the volatile matter of the remainder. It is, however, hardly possible to attain this, although it is said to have been approached in Sweden, in some instances, when the heaps were of the largest size. In this operation, even when performed under favorable circumstances, it rarely happens that 112½ lbs. of wood yield more than 17 of charcoal, while by distillation in a cylinder, the same quantity, as we have seen, yields 28 lbs. It is also impossible, in this method, to collect the pyrolignous acid or gas.

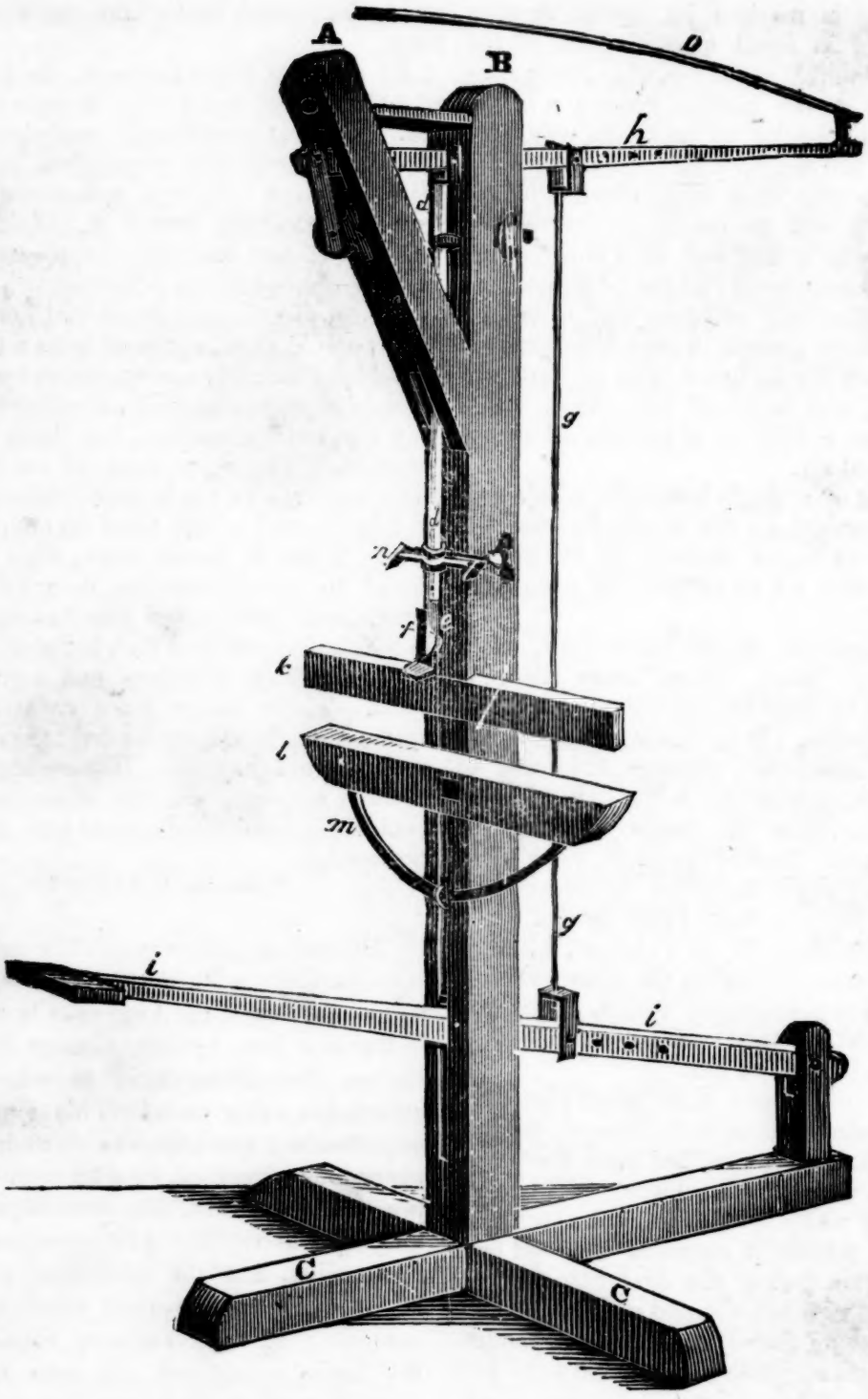
The waste which thus takes place, has led to various attempts to improve the process. Among these, has been the formation of moveable enclosures of basket-work, by which the pits might be surrounded, and which, if carefully guarded from combustion during the first time they are used, are so much charged with pyrolignous acid as to be thereafter almost incombustible. Another method is, to form the floor of the pit of iron sheets, or cast iron plates, beneath which is a cavity that serves as a furnace; no air holes need be left in this method, and thus little wood is burnt away. It has been proposed, by Mr. Marcus Bull, to effect the conversion into charcoal, at the expense of fuel of inferior value; for this purpose, the whole space between the logs is filled up with the refuse charcoal of former burnings, which, being more inflammable than wood, burns first, and chars the logs.

By either of these methods, the product of 112½ lbs. of wood may be raised to 22 lbs. The last is obviously easily practicable; as wherever the preparation of charcoal is carried to a large extent, the removal and handling leaves a considerable quantity of dust and small fragments which may be applied to the purpose.

At the Bennington furnace, (Vermont,) where the coal is obtained from a tract of wood land which has never before been cut, a mode of preparing charcoal, different from any we have described, has been put in practice. The trees were of so large a size, as to render the labor of cutting them in lengths, and piling them on end, excessive. They, in consequence, were not reduced to less dimensions than 12 feet in length, and were rolled together into piles in which they retained their horizontal position, and which, therefore, had a prismatic form. These heaps were covered with earth, and lighted from the top; the draught vents were at the ends. The management, in other respects, was the same as in the conical pits, and the charcoal was of superior quality.

(Concluded in the next.)

MORTICING MACHINE.—The following cut represents a Morticing Machine, exhibited at the Fair of the AMERICAN INSTITUTE, in October last, by Mr. George Page, of Keene, New-Hampshire, to which was awarded a *silver medal.* This simple and unpretending machine was viewed, and its operations witnessed, by a large number of practical mechanics, who were highly gratified by the rapidity and precision of its movements, and the wonderful accuracy of its work. Any person could, at once, perceive that, with ordinary care, and a few hours' experience, any man can perform as much labor in *one day*, with this machine, as in a *whole week* in the ordinary mode. Such, indeed, is the simplicity of its operation, and economy of its use, that over three hundred machines have been sold since the Fair in October last; and it is probably not too much to say, that the owners of them have, on an *average*, saved *twice the cost of them*, in addition to the



great advantage and convenience in forwarding work during the present scarcity and high prices of labor. A small proportion, however, of those mechanics who have morticing to do, have yet obtained them. A small number only of those journeymen who "work by the piece," have yet consulted their own interest by adopting them. A few, however, who view things properly, have got them, and are, consequently, enabled to do much more work, and, of course, to earn more money, than was possible before. If a man, who worked on bedsteads, for instance, which have much morticing, could formerly earn $15 a week, he can now do the same morticing in one-sixth or

one-eighth of the time, and, of course, do more work, and certainly do it better. Indeed, any man who has much morticing to do, will save the cost of a machine in a month, and even less.

This machine may also be used, with a little alteration, for morticing *hubs*, for carriages, waggons, &c.; and an experienced hand can prepare and mortice a sett of common-sized carriage hubs in ¾*ths of an hour*, with ease, and do them far more *accurately* than in the ordinary way.

The HUB MACHINE can be attached to the morticing machine, and the whole will not occupy, when in use, a space of over four feet by six in the shop, for the workman and his materials.

We are *un*-authorised, yet take the liberty of referring to the following gentlemen, who have machines in use, and who will probably give an opinion in relation to them:—

Talbot & Perry,	Prince st.,	used for	mahogany doors
James De Witt,	James st.,	do	do
Charles Baker,	Grand st.,	do	do
Mr. Lasher, 16	Downing st.,	do	do
J. Green,	Orange st.,	do	do chairs
James Berry,	Le Roy st.,	do	do
Hadden & Gedney,	Prince st.,	do	carpenters' work.
George Smith,	Prince st.,	do	do
George Webb,	Greene st.,	do	do
J. L. Black,	Amos st.,	do	do

Andrew Woodruff, Jefferson, corner of Henry st.
Clarkson Dey, 488 Broome st.,

An hundred others who have used them might also be named if it were necessary, but it is not, as all the descriptions and opinions in the world will not be as satisfactory to many as one half hour's observation of its operation; we therefore refer those who may desire to examine it, to the office of the manufacturer, No. 136 Nassau, corner Beekman street, or to the shops of the gentlemen whose names are given above for further evidence, if they desire it.

DESCRIPTION.

C, C, B, A, the *frame*, consisting of two cross pieces or sills, with an upright post from their centre, and a piece projecting upward in front, at an angle.

d, *d*, The slide, with a socket in the lower end, into which the chisel is inserted. This slide is of iron, connected with the lever *h*, and sustained in its place by two boxes, passing through the upright, which are regulated by thumb-screws on the side of the post.

e, The CHISSEL, a small but very important part of the machine. It is made of cast steel, about six inches in length, and from *one-eighth* to an inch in diameter.—The cut is perpendicular on *one* side, and beveling on the other, with *side cutters*, projecting backward about one-fourth of an inch, which serve not only to make the sides of the mortice as smooth as the ends, but also to clear the chips, as the chissel is withdrawn from the mortice.

This chissel is either *single*, or *double*, cutting one or two mortices of equal width and depth at the same time. It has also a tool for making *dowells*, and another for cutting holes in Venitian blinds, for the cord to pass through. The two latter are of much use, especially that for making dowells, or pins, of any size, from one-fourth to an inch in diameter, and 4 to 6 or 9 inches in length; and the other performs, at one pressure of the foot, an operation which in any other way requires five times the labor.

f, The stop, which is made fast to the upright by a bolt and thumb-screw, to prevent the timber from rising when the chissel is drawn up by the spring.

g, *g*, The connecting rod between the lever *h* and the treadle. This rod is movable to accommodate the depth of the mortice.

h, The *lever*, passing through the upright post and front brace, to which it is connected, in front, by two straps of iron. The lever, is about three feet in length, and at its extreme end connected with a spring-poll to raise the chisel from the mortice.

i, *i*, The treadle, or foot-board, by which the machine is put in motion. This foot-board is also, like the lever, about three feet in length; passing through a long mortice in the lower part of the upright post, and made fast *at the back end*, to a short upright standard, rising about 14 inches from one of the cross sills. It is then connected by an iron rod in the rear of the upright post,

with the lever at the top, which rests upon the slide *d*, *d*, into which the chissel is inserted. The lever *h* acts upon a pivot in *front*, resting, at about nine inches from the pivot, upon the top of the slide *d*, *d*, which is moveable—and is connected by a rod with the treadle *i*, *i*, which acts upon a pivot at its extreme *back* end. By placing one foot upon the foot board, and pressing it down, the back end of the lever *h* also descends, and causes the chissel to perform its office upon the timber, which is laid upon the rest *l*. It will be readily perceived that a powerful leverage is obtained by this arrangement, and that a rapid motion is easily produced with the foot, by which the chissel is driven into the timber, and drawn out again by the aid of the spring pole.

The timber to be mortice is held in its place on the rest *l*, until it receives a thrust from the chissel, when it is moved forward one eighth of an inch, by hand, or otherwise, as the chissel rises, and falls again by the aid of the foot. When the mortice is headed down at one end, to its proper depth, the chissel is turned the half of a revolution, by the aid of a spring and movable box *n*, and again confined, by a spring, in a proper position, and the timber is caused to retrace its course, and the mortice is completed to a uniform depth, and headed down at the other end; and, on turning it over, the chips will either drop out, or may be easily picked out, as the chissel is so constructed, with side cutters, as to cut at *both sides*, as well as at the end; and therefore the mortice is not only perfectly true, or uniform in its sides, but also smooth, or free from splinters, arising from cross grain, as is frequently the case in the ordinary mode of morticing.

k, A back board or fence, which serves to keep the timber parallel.

l, The *rest* or *bench*, on which the timber to be morticed is laid. It may be *raised* or *lowered*, or placed at any desired angle to suit the nature and size of the work.

m, The half-circle, by which the position of the rest is regulated.

n, The box and thumb-spring, by which he position of the chissel is regulated.

o, The spring-pole, (shown in part,) which acts upon the lever *h*, and of course the slide and chissel which are connected with it.

It will be readily perceived that, by pressing the foot-board down to C, the chissel *e* will be brought down in a perpendicular line near to the top of the rest *l*; and it may be repeated an hundred times a minute, and thereby cut a mortice three inches or more in depth, and six to twelve inches in length, according to the wood, in a minute.—[Ed M. M.]

From the Journal of the Franklin Institute.

REPORT ON THE USE OF THE HOT AIR BLAST IN IRON FURNACES AND FOUNDRIES. BY A. GUENYVEAU, ENGINEER AND PROFESSOR IN THE ROYAL SCHOOL OF MINES.

(Translated for this Journal, by Prof. A. D. Bache.)

Concluded from page 168.

II. *Application of the Hot Air Blast to Cupola Furnaces, to Smith's Forges, &c.*

The hot air blast appears to have been applied with great advantage, in England, in furnaces for remelting pig iron. The consumption of coke, per ton of iron, was reduced from 400 to 280 lbs., one ton of metal passing per hour. The blast was heated by an apparatus placed at the trunnel head. There are various advantages resulting from this application. The fusion of the metal takes place in about half the time required to melt it by the cold blast; it is thus less exposed to the injurious action of the blast, and while twice the quantity of iron can be melted in a given time, the quality of the material is better. It is further stated that the quallty of the iron is improved by the melting, and that it is more easily cast, owing to its greater fluidity.

At Vienne, France, there are two cupola furnaces supplied with hot air. The apparatus is at the trunnel head, and consists of two-bell-shaped vessels, through the interstice between which the draught is forced. This form of apparatus is decidedly bad, the alternate expansion and contraction of the parts renders it leaky in a very short time. The efficacy of the hot air blast is felt, however, even at this furnace.

In applying the heating apparatus at the trunnel head of furnaces, for smelting lead, copper, &c., care must be taken to protect the pipes from the sulphurous and me-

tallic vapors, which, issuing from the furnace, would destroy them very rapidly.

The fan, or rotary, blowing machine is used in several establishments at Paris, Rouen, &c. for supplying cupola furnaces with air. This though a simple means of applying power, does not seem to be an economical one. Even when great velocity is given to the fans, the force of the blast is inconsiderable, but by increasing the opening of the blast pipe, the quantity of air thrown in may be rendered very great. In one case at Rouen, by increasing the diameter of the tuyeres from 30 to 54 lines, the daily yield of the furnace was nearly doubled, and an economy of fuel (coke) of 20 per cent. resulted, the cold blast being used in both cases. At La Voulte the fan makes from 800 to 1000 revolutions per minute, and the pressure at the tuyere is only four-tenths of an inch of mercury. Three and a half to four inches is the ordinary pressure with other blowing machines. If the air were to be heated, this machine would be hardly applicable, as the friction in the tubes of the heating apparatus would tend materially to diminish the draught.

Unsuccessful attempts have been made both in England and France, to apply the hot air blast to bloomery furnaces.—The causes of failure are, however, not known.

A similar application to finery furnaces, using charcoal as fuel, has succeeded.—Mr. Combes states that at Lausen, (in Wirtemburg) the blast is heated by pipes below the earth of a finery furnace, and has its temperature raised to 390° Fah. With the cold air blast, they used 40 cubic feet of charcoal to produce 200 lbs. of bar iron, and the weekly yield of the furnace was 6,000 lbs. Now, with the hot air blast, they consume 30 cubic feet of charcoal to the two hundred pounds of iron, or about one part by weight of charcoal, to one of malleable iron; the weekly yield is from 7,200 to 7,800 lbs. On several occasions the consumption of charcoal per 200 lbs. of iron was as high as 36 cubic feet, which the workmen attributed to their using pig iron obtained by the hot air blast, which they considered more difficult to refine than that made with the cold blast.

This last conjecture is opposed to the experience at Konigsbronn, where they do not consider iron reduced by the hot air blast as difficult to refine. The economy of fuel by this method of refining, has been rather more than one-sixth, and the loss in rendering the iron malleable is diminished. This successful result is obtained by using the hot air blast in melting the metal, while it is decarbonized by the aid of the cold blast. This method of operating has been followed with success at the finery furnaces at Creusot and Decazeville.

I was present at some trials made upon a catalonia forge by an association of iron masters of the department of Ariege.—These were entirely unsuccessful. In the last of them the consumption of coal was not greater than with the cold blast, but the iron was of very inferior quality.

The hot air blast has been applied to the smith's forge with success. The iron was brought more rapidly to a welding heat, and the loss by oxidation was less than with the cold blast. There was no gain in the consumption of fuel. This method will probably be found useful in the working of steel, but no experiments have yet been made of a decisive character.

On the Use of Raw Coal, or of Wood, in High Furnaces, &c.

In order to produce a high temperature in a furnace, it is obviously necessary that the fuel should be consumed rapidly, and should not give off when heated, any vapors or incombustible gases, to carry off heat. The air thrown in by the draught contains four-fifths of its weight of nitrogen, which becoming heated causes a waste of fuel; if in addition to this vaporizable matters are present in the fuel, the loss of heat is greatly increased. Charcoal, coke, &c. make such hot fires because their volatile parts have been driven off by previous heating.

In high furnaces wood has been used to advantage, even in the smelting of iron, while it has failed in low ones. In the former the fuel descends slowly, and after having its temperature gradually raised, reaches the part of the furnace in which the blast is most operative. At this place the highest heat is to be found, and here the principal chemical changes take place. Thus in fact the fuel is gradually dried and carbonized before it reaches the place of greatest heat. If it were otherwise, the work-

ing of the furnace would be very unsatisfactory.

Experiment has proved the position just taken, however liable to objection it may seem on the score of the high heat which may be supposed, in every furnace, much above the tuyeres. It was found in the Hartz, by trial in a furnace of twenty feet in height, in which lead and copper ores were smelted, that the wood used as fuel came within six or eight inches of the tuyeres, without having been carbonized. The experiment was made by having small openings made at intervals in the stack, through which the progress of the operation could be examined. In this case the use of wood was abandoned, the furnaces being worked, as before, with charcoal.

A further proof of the same position may be drawn from the fact that raw coal, although substituted for coke, with advantage, in some high furnaces, has not been used in cupolas.

It is then absolutely necessary that the wood, or coal, should be converted into charcoal, or coke, before reaching the reducing part of the furnace. When this does not occur, and this is proved to be sometimes the case, the working of the furnace is unsatisfactory. The nature of the coal will produce different effects in the same kind of furnace. Thus at Alais a gradual deterioration in the working of the furnace resulted from the use of raw coal; at Creusot it was found necessary to mix the raw coal and coke in nearly equal proportions; in Scotland the hot air blast is required to enable them to use raw coal, while in Wales and at Decazeville they use raw coal with the cold air blast. The effect of the hot air blast is doubtless to facilitate the carbonization of the raw fuel.—To use wood for the smelting of iron, even in high furnaces, it has been found necessary to dry it before charging with it. This is true both in the Russian furnaces, and at Plons, in the latter of which the hot air blast is used, and the wood is mixed with charcoal. It should be observed further, that resinous woods, easily charred, have been the only ones hitherto tried.

This reasoning shows also why the more or less perfect roasting of an ore, the more or less moist state of the materials of the charge, the more or less complete carbonization of the wood or coal, produce such important effects, even in the largest furnaces. It is plain that the temperature just above the point when the ore is reduced is low, since coal, or wood, is not charred, and that to this we must look for the reason why it is so difficult to use these combustibles in the raw state.

M. Lampadius, of Freyburg, in his essay, "on the use of combustibles in their crude state,"* has shown how necessary it is to heat the wood, or turf, to a point near to that in which it begins to carbonize, before using it as fuel. He remarks that the cost of transporting wood or turf being, of course, much greater than the freight upon the charcoal from them, will prevent their use in many cases. Thus if it be supposed that there is a gain of twenty-five per cent in the quantity of charcoal, by using wood not carbonized, as was the case in the Russian furnaces, the balance would at Freyburg, be against the use of the raw material, on account of the cost of transportation. M. Lampadius concludes that when the material is at hand, or the cost of transportation low, uncarbonized wood may be used to advantage, in high furnaces, for smelting iron, if it has been duly dried; a result due to the heat given out in the combustion of the gases driven off from the wood, and to their reducing power.

The cause just assigned seems to me insufficient to explain the very great economy sometimes resulting from the use of the raw material; I consider the effect mainly due to the mode of carbonization, by which a much larger per centage of the carbonized fuel results than by the ordinary methods. The volatile parts of the fuel are driven off by the heated and incombustible gases passing through it, and there is no waste, by combustion. Being carbonized slowly, uniformly and without sensible waste, the greatest useful effect must result, and it is easily understood why a given weight of dry wood, or coal, may when thus circumstanced, yield a fourth, or even a half more charcoal, or coke, than it would by the ordinary method, and thus may be competent to reduce a fourth, or half more ore.

It must be admitted however, that this explanation does not account satisfactorily

*Erdmann's Journal of Chem. and Technology, vol. XII. 1831.

for the very great advantage found in the use of raw coal, in the high furnaces of Scotland, with the hot blast, and at Decazeville with the cold blast. At Decazeville, coal more than replaces an equal weight of coke. Thus one part by weight of coke was used for the fusion of 1.131 of mixed ore and flux, and now one part of coal is used to 1.675 of ore and flux. This coal would yield but .38 ($\frac{3}{8}$ths) of its weight of coke, and melt therefore but .43 of mixed ore and flux. The causes assigned by M. Lampadius, are therefore probably correct, being necessary in addition to that just examined, to explain the various effects.

On the Causes of the Efficacy of the Hot Air Blast.

It is plain that if cold materials are introduced within a furnace, they tend to lower its temperature, while their own is raised. If then the fuel and the blast be heated before they act chemically, to a temperature nearly equal to that of the part of the furnace at which the combination takes place, this heated portion will be increased in extent, its temperature will be higher than it would be under other circumstances, and the amount of heat, therefore, available in melting the ore, &c. will be greater. In smelting furnaces the fuel and ore are always thus heated. This is not the case, however, with the blast. In fact it has hitherto been considered an advantage to have the air as cold as possible, that it might contain more oxygen in a given bulk, and experience showed, in conformity with this view of the matter, that blast furnaces worked better in winter than in summer, and better at night than during the day.—The expansion of air by heat causing, under a given pressure, less oxygen to be thrown into the furnace, will produce a diminished consumption of fuel, and yield of metal. In wind furnaces, in reverberating furnaces, and generally in all where an ordinary draught is used, an increased temperature in the air diminishes the draught. It can only be increased by raising the temperature of the air in the furnace, by the use of a more freely burning fuel, by additional attention in firing, &c. The same difficulty occurs in the blast furnace, if the power of the blowing machine cannot be increased.

It so happens that at the very time the air is warmest, springs are lowest, and the condensation of steam most difficult, two facts which will explain why the working of furnaces, both as to quantity and quality, is better in winter than in summer. If the weight of air thrown into the furnace had been made the same in summer as in winter, by increasing the power of the blowing machine, and the area of the blast pipes, it is probable that the working would not have been worse, in the former season than in the latter.

An artificial heating of the blast should produce the same effects as that just alluded to, and it is by no means surprising that the efficacy of the hot blast has been doubted. It remains to be seen whence this efficacy results.

M. Dufrenoy* has, in his explanation of the advantages of the hot air blast, shown the difference between the quantities of heat introduced into the furnace with the hot and cold blasts, and in an assumed case has determined this difference to amount to about one-sixteenth of the heat evolved by the combustion of the fuel. Since less air is thrown into the furnace in using the hot blast, there is of course, on that account, less cooling effect to contend against than in the other case.

M. Clement Desormes concluded by calculating from data in an assumed case, that the temperature within the furnace is increased between 270° and 360° Fah. by the heated air blast; an increase which he considers adequate to explain all the observed effects.

These theories are far from settling entirely, the question in an economical point of view. They suppose indeed, that the consumption of fuel in heating the air may be equal to that saved in the reduction of the ore, which is by no means the case.

I propose therefore to classify the observed effects, and to point out their relative degrees of importance, and their connexion wtth each other and with established physical principles.

The effect of heating air being to diminish its density, and the consequences of this being decidedly bad when the air is but and there is no doubt a point at which this effect begins, and another beyond which it

* Annales des Mines, vol. IV. This Journal, page 419, vol XV.

would hardly be sensible. Observation confirms this explanation. Bars of iron are readily raised to a welding heat in a smith's forge, supplied with hot air, in half the time required by the cold blast, and as the same quantity of coal is consumed per day in both cases, the greater effect in the former can only result from an increased intensity of combustion.* In the most successful trials the air was heated to 370° and the diameter of the blast pipe not being changed, the quantity thrown in was actually diminished, and yet there was an increased consumption of fuel. It is then the temperature of the air, and not its density, which determines the intensity of the fire.

slightly heated, why should a further increase of temperature, even in a diminished pressure and density, produce so great advantages? The explanation is that the temperature of the air has a most important effect on the intensity of combustion,

In the furnace, then, the fuel is burned to the greatest advantage; but, further, the heat thus produced is rendered most effective.—There can be no doubt that, in order to the regular working of the furnace, the different layers of the charge must descend regularly and horizontally. By the hot air process, the fuel is more completely converted into carbonic acid, than in the old process; more fuel is consumed in a given place, the temperature of which is, therefore, higher than in the former case; and this place of intense heat is more extended. As consequences, a greater mass of ore is reduced in a given time by the same weight of fuel, and more refractory ores can be reduced.

The charges descend more slowly, probably, because it requires more time to consume a large quantity of combustible in a given place, than to burn it through a considerable extent of the furnace. The air being completely deprived of its oxygen in the lower part of the furnace, cannot consume any of the combustible higher up. The charges have all moisture, or gaseous matter, completely driven off by the hot gasses passing through them, and arrive, duly heated, at the place where the most intense heating effects are produced. This diminished rate of descent is entirely consistent with an increased yield of metal, since the amount of ore in each charge is increased.

From the intense action referred to above, results a greater fluidity in the slag, a diminution in the quantity of flux, the possible use of more refractory ores, or an increased proportion of others in the charges, and the production of gray pig iron, by proportions in the charge in a furnace, which, before, would yield only white, or mottled, castings.

In conclusion, it may be remarked that some changes may probably be made with advantage in the forms of furnaces using the hot air blast. It is difficult to point them out, and their determination will require repeated trials, and with the precise ores and combustibles intended to be used in a particular case. I would suggest, however, especially where forged iron is to be made, enlarging the furnace at and above the boshes, diminishing, at the same time, the height of the whole furnace.—This latter change is understood to have already been made with advantage, in certain furnaces using charcoal as a fuel.

*Anthracite coal merely requires its temperature to be sufficiently raised to make it keep up the combustion by the heat which it gives out. Iron wire, to burn in oxygen, requires its temperatures to be first raised, and may be burned in chlorine if first fired by the combustion of copper wire. Iron filings, finely divided, burn in the air, and in the experiments of Mr. Tyler, a fire was made in a smith's forge, from iron turnings, by raising the temperature with fine turnings. At last the whole burning mass was iron, and a welding heat was produced upon a bar thrust into it.—[Trans.]

RURAL SCENERY: THE THATCHED COTTAGE. BY JUNIUS.

There are but few objects in landscape scenery that form a more *rural* characteristic than the "thatched cottage," by the side of a wood, which serves to protect it from the cold winter blast, and has the effect of a shady retreat for summer. To impart to the traveller pleasing ideas of the fertility and domestic comforts, blended with rural economy, of the country through which he passes, is, perhaps, one of the very best criterions of his opinion of the more rapid improvement and increase of the value of property; and the 'cot' spoken of is one of the sure features to attract his particular attention.

There is something about a thatched cottage which is always inviting, and reminds

us of the comforts of life. I disagree with Dr. Johnson, who deems all things of a rustic nature, as the abode and choice of the unrefined; or, in plain words, expressive of rudeness in every degree.

I very much doubt if the greatest monarch is more intelligent, oftentimes, than those who dwell beneath a cottage of thatch; nor are his domestic comforts any more elevated or constant than the cottager, although fame extends his name to a more distant part, where rumor often falsifies his real charecter. The cottager rarely has any thing to fear on this subject, as his only object is to make *home* agreeable to himself and its inmates; and this effect being observable to the passer by, it engraves on his memory the *snug* appearance of the thatched cottage.

Snugness is not altogether the only feature displayed in such dwellings, but there is a character of retirement, blended with hospitality. By general observation, it will be seen that the sites of such dwellings are well chosen where the requisite comforts for domestic purposes are of easy access. Shelter and shade are the first consideration in this case, and are a grand feature, namely, the fine impression given on landscape scenery. The rustic construction of the cot is always pleasing when we can see natural materials in every way made useful, and not too much transposed into something, of which all recollection of its primitive state is lost, to appearance. The thatch, being of straw, reminds us of the utility it has been in another way—when the bearer of grain; and the rude unhewed post of the porch (on which twines the honeysuckle) of the use of forest trees The plan of the cot is mostly neat, and generally in the Gothic order, with the upper windows peeping out of the thatch. The approaches and appendages are always corresponding. The rustic arbor well covered with native grape vines that give a natural effect, and impart a luscious reward to the humble pruner. The approach is generally converted into neat and well kept flower-garden, which gives a healthy employment, or rather recreation, to an aged mother or some rosy cheeked prattling children, who are often seen strolling from their plot in quest of flowers to decorate the little parterre, transplanting them with care to their new habitations among, perhaps, some delicate exotics.

The vegetable garden, well filled with esculent vegetables and fruit, with a small orchard and meadow, are often appendages to the "thatched cottage." A running stream or brook in its vicinity gives a mellowness to the scene, and some rich verdant spots near the dwelling forms a part, of social effect, but seldom rivalled in landscape scenery.

Were I to choose a dwelling for retirement, when age wears off that activity and zeal from a life of bustle and business, it should be the cot above spoken of; not, gentle reader, that I would be conspicuous at that time of life, but because it would suit my desire. The wood would be a pleasing source for my researches of botanical specimens of native plants, and the trees and shrubs about my dwelling a fine retreat for the different kinds of birds which would visit my 'cot,' as their migrations suit their approach in the neighboring wood. The honeysuckle would impart, in the flowering season, a luscious repast to the little queen of birds—the humming-bird; and my flower-garden would serve to amuse my leisure hours in healthy employment. The fruit, raised by my care, would add to its flavor, and some to give to a friend, to friendship. A few choice books for my amusement, and to recall what had been seen and done in horticulture; and, at times, to read to relatives and friends, who should always find hospitality in my rustic manners, and the welcome repast of the wearied traveller, sums up my desire of a thatched cottage.

JUNIUS.

New Jersey, April, 1836.

ELECTRICAL SHOCK FROM A SHEET OF PAPER.

Place an iron japanned tea tray on a dry, clean beaker-glass, then take a sheet of foolscap writing-paper, and hold it close to the fire until all its hygrometic moisture is dissipated, but not so as to scorch it; in this state it is one of the finest electrics we have. Hold one end down on a table with the finger and thumb, and give it about a dozen strokes with a large piece of India-rubber from the left to the right, beginning at the top. Now take it up by two of the corners and bring it over the tray, and it will fall down on it like a stone; if one finger be now brought under the tray, a sensible shock will be felt, Now lay a needle on the tray with its point projecting outwards, remove the paper, and a star sign of the negative electricity will be seen; return the paper, and the positive brush will appear, In fact, it forms a very good extemporaneous electrophorus, which will give a spark an inch long, and strong enough to set fire to some combustible bodies, and to exhibit all the electric phenomena not requiring coated surfaces. If four beaker-glasses are placed on the floor, and a book laid on them, a person may stand on them insulated; if he then holds the tray vertically, the paper will adhere strongly to it, and sparks may be drawn

from any part of his body, or he may draw sparks from any other person, as the case may be; or he may set fire to some inflammable bodies by touching them with a piece of ice.

I beg to remain,
Yours, &c.
G. DAKIN.

Oxford, March 20, 1836.

We suppose that every one having occasion to clean paper with Indian-rubber during the past winter, has noticed the remarkable force with which the paper adheres to the table.

An Englishman has just erected, on the river Theiss, in Hungary, a mill in the form of a colossal man——the head being the dwelling house, the eyes the windows, the nose the chimney, and the machinery in the body, driven by a stream of water in a canal, in the form of an immense bottle, empying into his mouth.—[Daily Times.

METEOROGICAL RECORD,

For the month of November, 1835, kept at Avoylle Ferry, Red River, La., (Lat. 31° 10′ N., Long. 91° 59′ w.,) by P. G. VOORHIES.

NOVEMBER.

Days.	Morn.	Noon.	Night.	Wind.	Weather.	REMARKS.
1	52	64	60	calm	clear	
2	55	70	62	..	..	foggy morning
3	60	71	69	SE	cloudy	rain all night
4	65	64	64	calm	..	heavy rain all day and all night
5	64	65	65	SE	..	clear evening
6	58	65	61	calm	clear	
7	52	78	68	..	cloudy	
8	64	67	66	..	..	a little rain
9	62	66	64	..	..	rain at noon—clear evn'g
10	65	72	68	S	..	heavy rain and thunder all day
11	44	49	49	N	clear	
12	41	51	48	NW	..	first white frost
13	42	66	62	NE	..	. .
14	58	70	67	SE	cloudy	heavy rain all night
15	57	78	74	S	..	
16	58	64	60	calm	..	rain all day and all night
17	55	68	59	..	..	. . .
18	58	76	74	SW	..	
19	74	79	75	..	..	high wind at noon
20	71	78	66	calm	..	showers—rain at noon
21	57	59	56	NE	..	. all night
22	47	49	46	N	..	rain at noon and evening
23	42	50	45	NW	clear	
24	36	45	42	N	..	
25	32	47	46	NE	..	
26	38	50	48	calm	..	cloudy evening
27	41	43	42	..	cloudy	drizzling rain all day
28	38	54	43	..	clear	
29	32	51	48	..	..	heavy white frost
30	34	68	62	..	..	

Red River fell this month 3 feet—below high water mark 5 feet 11 inches.

METEOROLOGICAL RECORD.

For the month of December, 1835, kept at Avoylle Ferry, La., (Lat. 31° 10′ N., Long. 91° 59′ w.,) by P. G. VOORHIES.

DECEMBER.

Days.	Morn.	Noon.	Night.	Wind.	Weather.	REMARKS.
1	49	64	61	calm	clear	
2	50	65	63	NE	..	
3	51	70	68	SE	.	cloudy and calm in the afternoon.
4	55	75	67	calm	..	Red River rising
5	52	59	53	N	cloudy	clear at noon
6	34	64	56	..	..	white frost
7	38	67	53	calm	..	
8	51	59	52	..	clear	
9	53	62	56	..	cloudy	rain all day and all night
10	54	50	50	N	..	. . .
11	36	50	41	calm	..	
12	33	51	50	..	clear	heavy white frost
13	32	60	54	..	..	. .
14	40	62	59	..	..	white frost—cloudy in the afternoon
15	39	67	62	..	..	
16	41	68	62	..	..	white frost
17	46	72	67	..	cloudy	foggy morning
18	60	72	68	S	..	clear at noon and rain all night
19	67	74	68	SE	..	
20	58	76	54	NW	..	rain in the morning and clear in the evening
21	46	62	58	calm	clear	
22	43	53	49	..	..	heavy white frost
23	32	56	52	..	..	
24	52	58	65	SE	cloudy	rain all night
25	53	62	56	calm	..	light showers all day
26	54	64	57	..	..	Red River on a stand
27	49	55	51	..	..	clear at noon
28	44	61	58	..	clear	light white frost
29	42	48	62	..	..	Red River falling
30	45	70	66	..	..	
31	42	68	62	..	..	white frost

Red River rose this month 2 feet 3 inches—below high water mark 3 feet 8 inches.

Rail-Road.—A new locomotive engine on the Lowell Rail Road a few days since brought from Boston 190 tons, weight of engine, cars and loading included. The same engine without any load except the Tender, passed from the watering place to Lowell, a distance of fifteen miles in 20 minutes; that is at the rate of 45 miles per hour. This is quick time, forward march! Such a car as this would be convenient "to send after the Doctor."—[Railroad Journal.

PAMBOUR ON LOCOMOTION.

Continued from page 384.

The area of the two pistons (11 inches in diameter) being 190 square inches, a pressure of 5.5 lbs. per inch, produced on the piston a force of 190×5.5 lbs. $= 1{,}045$ lbs. at the velocity of the piston, and thus a draft of $\frac{1.045}{5.887} = 177.5$ lbs. at the veloci-

ty of the engine. That was then the force required to move the engine and its tender. Now, the tender filled with water and coke, weighed 6.50 tons, and according to the experiments made on the friction of the carriages, each ton required to put it in motion a power of 8 lbs. The tender consumed, therefore, for its share, a force of 6.50 lbs. + 8 = 52 lbs. Thus the resistance proper to the engine was 177 lbs.—52 lbs. = 125 lbs.

III. On July 23, the same engine, the SUN, was tried again at the least pressure, and gave the following results :—

At 4 lbs. marked on the balance, the engine started, followed by its tender filled with water and coke.

At 1 lb. marked on the balance, it started rapidly.

At 0 of the balance, it still started with facility.

At 2 lbs. under zero, it still moved at the rate of two or 3 miles an hour.

At that instant it was put under the mercurial gauge, which marked 4¾ lbs. We may consider that, in this experiment, we had arrived at the lowest pressure by which the engine could move. According to the calculation established above, that pressure of 4¾ lbs gave a force of 902.5 lbs., which, referred to the motion of the engine, produced a traction of 153 lbs. Deducting 52 lbs for the resistance of the tender, there remained 101 lbs. for the resistance of the engine.

IV. The same day, the FIREFLY engine, cylinders 11 inches, stroke 18 inches, weight 8.74 tons, wheels 5 feet, one pair of wheels worked only by the piston, was submitted to the same trial.

At 3 lbs. marked on the balance, it started, followed by its tender filled with water and coke.

At 2 lbs. also.

At 0 it started also, came back, and went off again in a contrary direction.

At 1 lb. under 0, it still started forwards and backwards. The pressure diminishing a little more, the engine has just power enough to move.

At that moment it was brought to the mercurial gauge ; the pressure was found to be 4½ lbs. According to the proportions of the engine mentioned above, a pressure of 4½ lbs. per square inch on the piston, produced a traction on the engine of 163 lbs. ; deducting 52 lbs. for the tender, there remained for the proper resistance of the engine 111 lbs.

§ 3. *Friction of the Engines determined by the Dynamometer.*

While the resistance of the engines was being determined in that manner, other trials were also made, to obtain a valuation of that same resistance by means of the dynamometer.

V. On July 22, in the morning, the VULCAN engine, cylinders 11 in., stroke 16 in., wheels 5 ft., weight 8.34 t., one pair of wheels only worked by the piston, being ready to set off for Manchester, its boiler full of water, and its fire-box of coke, was separated from its tender. A circular spring-balance was fixed to the engine, and a lever was passed through the ring of the balance, so that two men might draw the engine by means of the lever.

The engine was first put in motion by five or six men. The first impulse being given, the two men that pushed on the lever maintained it without difficulty in motion, at the rate of two or three miles an hour. The index of the balance oscillated very much. It varied generally from 130 to 170 lbs., giving an average traction of of 150 lbs.

The balance was afterwards taken off from the front of the machine, and fixed behind on the Liverpool side, when the same experiment repeated, gave an aver age traction of 140 lbs. The index still oscillated about 20 lbs. above and below that point.

Average of the two experiments, 145 lbs.

The engine was ready to go off, and it had already made some turns on the rails, in order to light its fire and fill its boiler, so that the grease that anointed the rubbing parts was melted, and the oil perfectly liquid. But the experiment taking *place* in the interior of the Liverpool station, in a great thoroughfare, the rails were covered with cinders and dirt; a circumstance which considerably augmented the resist ance to the motion.

VI. On July 23, in the evening, the SUN engine, of which the proportions have already been givnn above, and the weight of which is 7.90 t., was tried in the same man ner. It gave 100 lbs. traction towards Manchester, and 130 lbs. backwards, to-

wards Liverpool. Average 115 lbs. The boiler of the engine was full of water; the fire-box empty.

VII. On the same day, the FIREFLY, already described, the weight of which is 8.74 t., drawn by the dynamometer, required 125 lbs. in one direction, and 130 lbs. in the other. Average traction 127½ lbs. The boiler of the engine was full of water; the fire-box was empty.

VIII. On the same day, the FURY engine, cylinders 11 in., stroke 16 in., wheels 5 ft., of which only one pair are worked by the piston, weight 8.20 t., required in advancing towards Manchester 100 lbs. traction, and 110 lbs. going back towards Liverpool. Average 105 lbs.

These experiments took place on the engines separated from their tenders. They were made on a part which is considered as being exactly level. We may, however, suppose, that on the precise spot where the engine was, the soil was not perfectly horizontal, and that that was the cause of the slight difference in the resistance, observed between one direction and the other.

§ 4. *Friction of the Engines calculated by the Angle of Friction.*

These results did not differ considerably from the preceding ones; but as in all the experiments, the index of the balance varied extremely, in consequence either of the slight inequalities of the road, or of the jerks given by the men that drew the engine, the average traction was very difficult to ascertain exactly. Besides, the dirtiness of the rails augmented considerably the resistance. It was, consequently, desirable to get those results verified by a different method, admitting of greater accuracy.

For that reason the same engines were submitted to experiments similar to those which had served to calculate the friction of the wagons.

IX. On July 30, the JUPITER engine, cylinders 11 in., stroke 16 in., wheels 5 ft., only one pair of wheels worked by the piston, weight 7.90 t., was brought on the inclined plane of Sutton, to the same place where the experiments on the friction of the wagons had been made. It was separated from its tender, and left to its gravity on the plane.

Gone off from the post No. 0, it continued its motion until 249 ft. beyond the post No. 18, and ran during 7′ 12″. This experiment gives: Distance travelled, 6189 ft.; difference in level between the points of departure and arrival, 36.78 ft.; consequently, friction $\frac{1}{168}$ of the weight, or $\frac{7.90\text{ t.}}{168.} = \frac{17{,}696\text{ lbs.}}{168} = 105$ lbs. This result includes the direct resistance of the air at a velocity of 9 to 10 miles an hour.

X. On July 31, the ATLAS engine, cylinders 12 in., stroke 16 in., wheels 5 ft., four wheels coupled, weight 11.40 t., was brought to the same place. Not having been in time, the train could not be stopped precisely at the suitable point, and the engine was already 99 ft. beyond the post No. 1. It was not possible to push back the considerable train it was drawing; so that the starting-point having been carefully determined, the engine was left to itself at that point, and ran to 273 ft. beyond the post No. 17.

The distance travelled by the engine was 5454 ft., and the difference in level between the points of departure and arrival, 32.07 ft. Thus the friction was $\frac{1}{170}$ of the weight, or 150 lbs. This calculation includes the direct resistance of the air, at an average velocity of 8 to 9 miles an hour.

XI. On August 1, the same engine, the ATLAS, brought to Sutton inclined plane, and the centre of the engine being carefully placed facing the usual starting-post, was left to its gravity on the plane. It ran until 45 ft. beyond the post No. 14.

Distance travelled in 5′ 40″, 4665 ft., total descent 35.40 ft.; friction $\frac{1}{132}$ of the weight, or 194 lbs.

The engine had been repaired the night before. The connecting-rods being too weak had been changed, and the new ones were not yet exactly adjusted to their proper length. The resistance they produced, acting upon the wheel at the end of a lever of one foot, which is the radius of the crank-arm by which they turn the wheel, produced the effect of a powerful brake to check the velocity of the engine. This friction of the ATLAS is, consequently, not applicable to the experiments made with that engine before August 1.

XII. On August 1, the VESTA engine, cylinders 11⅛ in., (this engine had originally cylinders 11 in. diameter, but in repairing it, the cylinders were newly bored,

which augmented their diameter by one-eighth of an inch,) stroke 16 in., wheels 5 ft., two wheels only worked by the pistons, weight 8.71 t., was submitted to the same trial. Setting off from post No. 0, it continued in motion to 33 ft. beyond post No. 11. It ran thus in 6′, over a space of 3663 ft., with a difference in level between the departure and the arrival of 33.07 ft.; which establishes the friction at $\frac{1}{104}$ of the weight, or 187 lbs.

This engine had been repaired, since which it had only made two or three trips at the time of the experiment. The different pieces were not yet well fitted, nor the joints very easy. Thence arose the increase of resistance observed in it, comparatively with the other engines.

XIII. On August 2, the FURY engine, cylinders 11 in., stroke 16 in., wheels 5 ft., not coupled, weight 8.20 t., left the usual starting-point, and stopped at 48 ft. beyond the post No. 18, running in 7′ over a space of 5,988 ft., with a difference of level between the points of departure and arrival of 36.68 ft.; which puts the friction at $\frac{1}{163}$ of the weight, or 113 lbs.

XIV. On August 2, the VULCAN engine, cylinders 11 in., stroke 16 in., wheels 5 ft., not coupled, weight 8.34 t., left to its gravtiy from a point situated at 27 ft. above the usual starting-point, ran in 6′ 30″ over a space of 5,391 ft. with a difference of level of 36.52 ft., which puts the friction at $\frac{1}{148}$ of the weight, or 127 lbs.

XV. On August 4, the LEEDS engine, having the same proportions as the FURY and the VULCAN, weight 7.07 t., ran in 6′ 30″ over a space of 5,472 ft., on a slope of 36.32 ft. Thus the friction of the engine was $\frac{1}{150}$ of its weight, or 105 lbs. (one of the pistons of the engine creaked for want of greasing.)

XVI. On August 15, the same engine, the LEEDS, went off from the same point, and ran over 5,061 ft. in 6′, on a slope of 35.86 ft., which puts the friction of this engine at $\frac{1}{141}$, or 112 lbs. (one of the pistons creaked, as in the foregoing experiment.)

All these results include the direct resistance of the air against the engine, at an average velocity of 10 to 12 miles an hour.

§ 5. *Table of the results of the foregoing Experiments on the Friction of Engines.*

Placing all those experiments next to each other, we form the following table:—

EXPERIMENTS ON THE FRICTON OF LOCOMOTIVE ENGINES.

Number of the experiment.	Date of the experiment.	Name of the engine.	Diameter of the cylinder.	Stroke of the piston.	Diameter of the wheel.	Weight of the engine.	Mode of determination.	Friction resulting from the experiment	Friction of the engine.	OBSERVATIONS.
	1834.		inches.	inches.	feet.	tons		lbs.	lbs.	
I -	July 5	ATLAS .	12	16	5	11.40	by the least pressure	154	152	The engine has 6 wheels, 4 of which are worked by the piston.
X -	July 31	—	12	16	5	11.40	by the angle of friction	150		
XI -	Aug. 1	—	12	16	5	11.40	by the angle of friction	194	194	The connecting rods working hot.
II -	July 21	SUN . .	11	16	5	7.91	by the least pressure	125	114	
III -	July 23	—	11	16	5	7.91	by the least pressure	101		
VI -	July 23	—	11	16	5	7.91	by the dynamometer	115		
IV -	July 23	FIREFLY	11	18	5	8.74	by the least pressure	111	119	
VII -	July 23	—	11	18	5	8.74	by the dynamometer	127		
V -	July 22	VULCAN	11	16	5	8.34	by the dynamometer	145	136	
XIV -	Aug. 2	—	11	16	5	8.34	by the angle of friction	127		
VIII -	July 23	FURY . .	11	16	5	8.20	by the dynamometer	105	109	
XIII -	Aug. 2	—	11	16	5	8.20	by the angle of friction	113		
XV -	Aug. 4	LEEDS .	11	16	5	7.07	by the angle of friction	105	108	
XVI -	Aug. 15	—	11	16	5	7.07	by the angle of friction	112		
IX -	July 30	JUPITER	11	16	5	7.90	by the angle of friction	105	105	
XII -	Aug. 1	VESTA .	$11\frac{1}{8}$	16	5	8.71	by the angle of friction	187	187	The engine rather stiff, having just come from repairing.

Considering these results, we see that, setting aside the VESTA, which was particularly circumstanced, the locomotive engines, with uncoupled wheels, had an average resistance of only 115 lbs.; and the ATLAS, with coupled wheels, and of a considerable weight, only 152 lbs., when not thwarted by his connecting-rods.

However, to provide a datum for all cases, it may be concluded from the total weight of the engines, compared with their friction, that locomotive engines, well constructed and in good order, have a resistance of 15 lbs. per ton of their weight. This is the result which may be reckoned upon, when an engine is not yet constructed, and when, consequently, one can estimate only by guess what will be its future friction.

We have already observed, that the experiments with the dynamometer and by the least pressure, were made on a spot where the rails offered more resistance than along the line. On the other hand, the experiments on the angle of friction took place at a point of the railway where there were nine crossings to get over. These obstacles acted more particularly on the engines, because they occurred in a place where the velocity of the motion was already considerably dimmished. We may, therefore, when we have engines well constructed, kept in good repair, and on the Liverpool model, calculate on the result we have obtained, without fear of putting the resistance too low.

In each of the experiments with the engines, which we shall have occasion to relate, we shall take not the average result, but the individual friction of each of them, as it has been determined.

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ARTICLE II.

OF THE ADDITIONAL FRICTION OF LOCOMOTIVE ENGINES, IN PROPORTION TO THE LOAD THEY DRAW.

§ 1. *Of the Mode of Calculation.*

We have now determined the friction or resistance of locomotive engines, when they draw no load. We have, however, already shown, that the friction must increase in proportion to the load the engine draws. The aim of our researches must, therefore, now be, to discover the amount of friction for different loads, in order to deduce from it the surplus of resistance created in the engine by each ton of the load.

When an engine executes the traction of a train, we know the pressure in the boiler by inspecting the spring-balance; but we do not know the pressure of the steam in the cylinder, because, in passing from the boiler to the cylinder, the elastic force of the steam changes, as will be seen hereafter. If we could know, *a priori*, the pressure in the cylinder; if, for instance, it were possible to apply a mercurial guage to it, we might immediately deduce the friction of the engine corresponding to that load.

In fact, if by hypothesis we know the pressure in the cylinder, or on the piston, by calculating the total effect of that pressure on the area of the piston, we find the exact valuation of the power applied by the engine,

On the other hand, we also know the resistance opposed to the motion; it being composed of the resistance of the train and of the engine.

Besides, if the engine, in drawing that load, increased constantly in velocity, it is clear that there would be an excess of power over the resistance. If, on the contrary, the velocity were to diminish gradually, the power would be inferior to the resistance; but if we take the engine at the moment it has acquired a certain uniform velocity, and if that velocity be maintained without alteration, the power the engine thus applies must necessarily be exactly equal to the resistance it undergoes, or else there would be either acceleration or retardation in the motion.

Thus we know the power applied by the engine; we know the resistance to the motion, which is the sum of the resistance of the train and that of the engine; and, besides, this sum is equal to the power applied: consequently, the resistance of the engine is equal to the power applied, less the resistance of the train.

This mode would give thus immediately the friction of the engine, if we knew the pressure in the cylinder.

But there are cases in which the pressure in the cylinder is known *a priori*, and is equal to the pressure in the boiler. These cases are those in which the engine attains the limit of its power with the pressure at

which it is working; that is to say, when it draws the greatest load it can draw with that pressure.

In fact, as by the hypothesis the engine has arrived at the limit of its power, the pressure in the cylinder cannot be less than in the boiler; for, if it were, by diminishing the velocity, which is the only obstacle to the establishment of an equilibrium of pressure between the two vessels, one might give to the steam time to rise in the cylinder until it would equal the pressure in the boiler, and then the effect would be augmented. That is to say, that the engine might draw a greater load, provided its velocity were diminished. On the contrary, as soon as the pressure in the cylinder becomes equal to that in the boiler, there is no further diminution of velocity that will permit to increase the load; for an increase of load requires an increase of moving power, which is no longer possible.

Thus, in case one has attained the *maximum* load of the engine, the power applied is known *a priori*; and one may, as we have actually done above, deduce from it the corresponding friction of the engine.

Let us then suppose, that in an experiment we have attained the limit of the power of the engine. Let d be the diameter of the piston, and π the ratio of the circumference to the diameter, $\frac{1}{4}\pi d^2$ will be the area of the piston, and $\frac{1}{2}\pi d^2$ the area of the two pistons together. Let also p be the effective pressure per unit of surface of the steam in the boiler, such as it has been observed during the experiment; it is clear from what we have said above, that $\frac{1}{2}\pi d^2 p$ is the force then applied to the piston.

Calling D the diameter of the wheel, and l the length of the stroke, the force applied to the piston is, when transferred to the engine, reduced in proportion to their respective velocities, or in the proportion of $\frac{2l}{\pi D}$. Thus, after its transfer to the engine, it is expressed by

$$\tfrac{1}{2}\pi d^2 p \times \frac{2l}{\pi D} = \frac{p d^2 l}{D},$$

which is the expression of the power of traction as applied to the progress of the engine.

On the other hand, M being the weight of the load, expressed in tons, and n representing the resistance for each ton of the load, such as we have determined it in the preceding chapter, nM is the resistance of the train. Finally, if we represent by X the proper resistance or frictien of the engine,

$$n\mathrm{M} + \mathrm{X}$$

will be the total resistance offered to the motion of the engine.

Having seen that, when the motion is uniform, the power applied by the engine is equal to the resistance, we have

$$\frac{p d^2 l}{D} = n\mathrm{M} + \mathrm{X};$$

and finally,

$$\mathrm{X} = \frac{p d^2 l}{D} - n\mathrm{M},$$

which equation gives us the value we sought of tbe friction of the engine.

In this equation p is the effective pressure in lbs. per square inch in the boiler; d the diameter of the piston expressed in inches; l the length of the stroke; and D the diameter of the wheel, both expressed either in inches or in feet, which is indifferent, the equation containing only their ratio. The number n, which is the resistance per ton, is 8 lbs.; and thus the value of X, when found, will also be expressed in lbs.

Here, as well as in the experiments made above with engines without load, we do not, in calculating the resistance, take into account the atmospheric pressure; because, also, in calculating the power, instead of reckoning the *total* pressure of the steam, we only reckon its surplus above the pressure of the atmosphere. In doing this, we only suppress on each side two equal forces which equilibrate. Having here, as before, only to compare the power and the resistance in a case of equality, the substraction of an equal quantity can take place on both sides without altering the result.

The formulæ we have obtained is very simple, and the principle it represents will easily give us the resistance of the engine, in all the cases in which it has attained the limit of its power. All that remains to be done, is therefore to arrive at tha point.

In consequence, experiments were made in that view, sometimes taking the greatest loads the engine was able to draw, and at others only middling loads, but lowering the pressure, by means of the spring-balance, as much as possible, without stopping the train.

Those experiments were made on three

inclined planes of the Liverpool and Manchester Railway; viz. Sutton plane inclined at $\frac{1}{89}$; Whiston plane inclined at $\frac{1}{96}$; and the rise of Chatmoss at $\frac{1}{1300}$.* In estimating the resistance on these planes it is clear that the gravity of the mass, decomposed along the plane, forms an additional resistance to the friction of the carriages; so that the resistance of the train, not including the friction of the engine, is then composed of the friction of the wagons, at the rate of 8 lbs. per ton, and moreover of the gravity of the total mass in motion on the plane. Thus a train of 40 t., drawn by an engine weighing 10 t., offers on Sutton inclined plane the following resistance:—

	lbs.
40×8 lbs. = 320 lbs. friction of the carriages at 8 lbs. per ton, . . .	320
$\frac{40 \times 2240 \text{ lbs.}}{89} = 1{,}006$ lbs. gravity of the 40 t. (reduced in lbs.) on a plane inclined in the ratio of $\frac{1}{89}$,	1,006
$\frac{10 \times 2240 \text{ lbs.}}{89} = 251.6$ lbs. gravity of the engine on the same plane, . .	252
Total resistance, not including the friction of the engine, ...	1,578

And as we know that on a dead level a ton only requires 8 lbs. traction, we see that the train going up the plane is equal in that circumstance to a load, on a dead level, of $\frac{1578}{8} \times 197\frac{1}{4}$ t.

This is the manner in which the calculation will be made in the following experiments.

We give a considerable number of experiments because having to apply to the wagons their average resistance per ton, the greater the number of carriages, the more accurate will be the calculation.

§ 2. *Experiments on the additional Friction of Engines.*

I. On July 22, 1834, the VULCAN engine, cylinders 11 in., stroke 16 in., wheels 5 ft., weight 8.34 t., ascended *Sutton* inclined plane with a first-class train of nine carriages, amongst which the mail and two empty trucks; weight of the train, tender included, 39.07 t.

The velocity of 26.6 miles, before arriving at the plane, settled at the rate of 20 miles an hour for the first half of the ascent, took then an average of 11.42 miles, and went down to 7.5 miles in the last quarter of a mile of the ascent, which is a little steeper than the rest.

The spring-balance of the engine, fixed at 31, as a point of departure, marked 36, which by the mercurial gauge corresponds to 57.5 lbs. effective pressure per square inch.

In consequence of the proportions of that engine, we have:

190 area of the two cylinders in square inches, multiplied by
57.5 lbs. pressure of the steam per square inch in the boiler or on the piston, makes
10,925 lbs. force applied on the piston; which being transferred as a power of traction to the engine, the velocity of which is 5.887 times greater, gives
$\frac{10{,}925}{5.887}$ lbs. = 1856 lbs. power applied to make the engine advance.

On the other hand, the resistance was

39.07×8 lbs. =.....313	lbs. resistance, owing to the friction of the carriages.
$\frac{47.41 \times 2240 \text{ lbs}}{89}$. = 1193	resistance owing to the gravity of the total mass, train and engine.
1506	total resistance.

Thus:

1,856 lbs.	power applied.
—1,506	resistance, equal to 168¼ t. on a level.
350	corresponding friction of the engine.

As we have said, the average velocity of the ascent was 11.42 miles per hour, and the velocity at the top of the plane 7.5 miles per hour.

In all the experiments we give those two velocities separately, because the engine having a great impulse on arriving at the

* See the Section of the Liverpool Railway, Chap. V., Art. VII., § 1.

plane, we wish as much as possible to disengage that acquired velocity from the velocity proper to the motion. If we were to take 11.42 miles as the velocity of the motion, it would be a little too much, being complicated with the first impulse. On the other hand, by taking 7.5 miles we should commit a contrary error, because the last quarter of a mile of the ascent is steeper than the rest, and surpasses the inclination of $\frac{1}{860}$, on which our calculation is founded.

They call the first-class trains those which carry travellers, and go from Liverpool to Manchester without stopping. The carriages of those trains are never weighed. In all the experiments we have calculated them at an average weight of 4.73 t. loaded, and the mail coach at 3.44 t. The tender is reckoned at the rate of 5 t., or 5.50 t. according to the quantity of water and coke it contains at the moment of the experiment. The weight of the wagons, whether empty or loaded, is taken *exactly* in tons, cwts., quarters, and pounds. To simplify we shall express it here in tons and decimal fractions of tons.

II. On July 22, 1834, the same engine, the VULCAN, ascended *Whiston* inclined plane with a first-class train of 9 carriages, amongst which were the mail and two loaded trucks; weight of the train, tender included, 41.32 t. The velocity remained uniform during the ascent at 18.75 miles an hour, diminishing only to 12 miles an hour on the last quarter of a mile. The balance fixed at 31 marked 36, or effective pressure by the mercurial gauge 57.5 lbs. per square inch in the boiler.

This experiment gives:

lbs.

1,856 power.

1,489 resistance, equal to 186 t. on a level.

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367 corresponding friction of the engine.

III. On July 23, 1834, the ATLAS, cylinders 12 in., stroke 16 in., wheels 5 ft., weight 11.40 t., balance fixed at 50 lbs. as a point of departure, started from Liverpool with a train of 40 wagons weighing exactly 190 t., and, including the tender, 195.50 t.

The help of two other engines was necessary for the moment of starting. On *Whiston* inclined plane the train was helped by four engines; viz. two in front of the train, the AJAX and the EXPERIMENT, and two behind, the SUN and the GOLIATH. Drawn thus by five locomotive engines, the train went up the plane without a moment's delay; and once at the top, the ATLAS resumed alone the haulage.

Arrived at the rise of *Chatmoss*, the engine with its whole train, ascended it without help for a space of 5½ miles. Its velocity was however considerably reduced. The first six quarters of a mile were travelled with an uniform velocity of 15 miles an hour, pressure 51 by balance, or 54 lbs. by the mercurial-gauge. During the four following quarters the velocity was 10 miles an hour, same pressure. Here began a steeper ascent for half a mile. At this point the velocity decreased rapidly. During the first quarter of a mile it fell from 10 miles to 6 miles an hour; during the second it fell to 3½ miles, and continued diminishing to the end of the pass. In proportion as the velocity diminished the pressure rose; first to 51½, then to 52 by the balance, where it stopped, pressure corresponding with 55 lbs. by the mercurial-gauge. After the passage of the obstacle the velocity increased again to 4½ miles, then to 7½ miles an hour; after which it settled again for the rest of the ascent at its regular rate of 15 miles an hour. At the same time the pressure went down again to 51 by the balance, or 54 lbs. by the mercurial-gauge.

At passing a second similar irregularity of short duration, near the bridge on the Bridgewater Canal, the same effects were produced. The velocity was again reduced to 3½ miles, and the pressure rose again to 52 by the balance.

The irregularity which exists on Chatmoss is an inclined plane rising at the rate of 8 feet per mile, or $\frac{1}{660}$, and the other parts of the moss have a much smaller inclination, so that the average inclination is no more than $\frac{1}{1320}$; but the difficult pass is only half a mile long. When a mass of 200 t. arrives with a velocity of 15 miles an hour, and has consequently a considerable momentum, an obstable, the inclination of which is moderate, and lasts only for half a mile, cannot completely destroy the first impulse. The engine not having been able, during its passage over the obstacle, to acquire an uniform velocity, but

continuing on the contrary, to the last moment, to lose some of its speed, showed that that obstacle was too much for it; but the fact, ascertained on a length of 5½ miles, proved that the average inclination of the ascent, or $\frac{1}{1300}$, was within the limits of its power, with a pressure of 55 lbs. per square inch.

This experiment having given rise to some doubts on the real proportions of the ATLAS, we measured them ourselves a few days afterwards, on August 8, 1834, when the engine was under repair, and they were found perfectly exact. The diameter of the cylinder is 12 in.; the stroke, measured on the crank of the axletree then separated from the engine, 16 in.; wheels 5 ft., at the part that rests on the rail, with three-eighths of an inch more near the flange, and the three-eights less at the basiled part.

This experiment, taken on the irregularity of Chatmoss, gives:

lbs.
2,111 power of the engine.
2,226 resistance opposed by the load on the accidental slope at $\frac{1}{800}$.

—155 power minus.

The resistance exceeded the power. It was consequently really impossible for the engine to settle at an uniform velocity, during its passage over the obstacle. It was necessarily compelled to lose constantly of its speed, and would have stopped if the obstacle had lasted any longer.

But, taken on the average rise at $\frac{1}{1300}$, we have:

lbs.
2,111 power.
1,921 resistance of the train, equal to 240 t. on a level.

190 corresponding friction of the engine.

The average velocity during the experiment was 8 miles an hour; the least velocity 3½ miles an hour.

IV. The same engine, on the same day, travelling with the same train over *Rainhill* flat, which is a dead level, attained an uniform velocity of 9.23 miles an hour; the balance fixed at 50 marked 50.5, or effective pressure 53.5 lbs. by the mercurial-gauge.

lbs.
2,054 power.
1,564 resistance of the train, equal to 195½ t. on a level.

490 corresponding friction of the engine.

V. On July 23, 1834, the same engine, the ATLAS, ascended *Sutton* with a part of its train, consisting of 8 wagons, weighing 33.90 t. besides tender, and 39.40 t., tender included; balance fixed at 50 and marking 52, or effective pressure 55 lbs.; velocity 6 miles an hour.

lbs.
2,111 power.
1,594 resistance, equal to 199¼ t. on a level.

517 corresponding friction of the engine.

VI. On July 24, 1834, the FURY, cylinders 11 in., stroke 16 in., wheels 5 ft, weight 8.20 t., ascended *Whiston* with a train of 10 wagons, weighing together 51.16 t., and 56.16 t. with the tender; balance fixed at 32 and marking 35, or effective pressure by the mercurial-gauge 65½ lbs. per square inch in the boiler; average velocity 6.31 miles an hour, reduced to 3.33 miles at the top of the plane.

lbs.
2,114 power.
1,951 resistance, equal to 244 t. on a level.

163 corresponding friction of the engine.

VII. On July 24, 1834, the same engine, the FURY, ascended *Sutton* with a train of 10 wagons weighing 43.80 t., and 48.80 t. including the tender; balance fixed at 32 and marking 36, or effective pressure 67 lbs.; velocity 15 miles an hour. The engine drew its train with evident ease.

lbs.
2,162 pewer.
1,825 resistance, equal to 228 t. on a level.

337 corresponding friction of the engine.

VIII. On July 31, 1834, the ATLAS, of which the proportions have already been given, cannot ascend *Whitson* with a load of 14 wagons weighing 61.65 t., and 67.15 t. tender included, though the balance had been carried to 57, as point of departure, and marked 60, or effective pressure 63 lbs. per square inch in the boiler.

lbs.	
2,419	power.
2,370	resistance, equal to 296¼ t. on a level.
39	surplus of the power over the resistance, not sufficient to overcome the friction of the engine.

IX. On July 31, the same engine, the ATLAS, cannot ascend *Sutton* with a train of 8 wagons loaded and 4 empty, weighing 35.15 t., and 40.15 t. tender included. The balance had been purposely lowered to 40, as point of departure, and marked 42½, or effective pressure by the mercurial-gauge 46 lbs. per square inch. The velocity from 20 miles an hour, as it was before arriving at the plane, fell immediately to 7½ miles in the first quarter of a mile; in the second quarter it fell to 4¼ miles; in the third to 2¼ miles, and at last the engine stopped.

lbs.	
1,766	power.
1,619	resistance, equal to 202⅓ t. on a level.
147	surplus of power over the resistance, not sufficient, as we see, to overcome the friction of the engine. We have seen that the friction of this engine, even without a load, is 152 lbs.

X. At the conclusion of the latter experiment, and just at the moment when the engine stopped, the balance was raised to 45, and marked 47½, or effective pressure by the mercurial-gauge 51 lbs. With that pressure the engine regained velocity by degrees, and attained an uniform velocity of 7½ miles an hour, with which it reached the top.

lbs.	
1,958	power.
1,619	resistance, equal to 202⅓ t. on a level.
339	corresponding friction of the engine.

XI. On August 1, 1834, the VESTA, cylinders 11⅛ in. (this engine had originally cylinders of 11 in., but, in repairing them, they were bored again and acquired a diameter of 11⅛ in.,) stroke 16 in., wheels 5 ft., weight 8.71 t., with a train of 10 wagons weighing 43.72 t, and 49.22 t. tender included, ascended *Whiston* until within 60 yards of the top. There the engine was on the point of stopping, and several men were obliged to push very hard at the wheels in order to enable it to attain the summit. Balance fixed at 20½, and marking 23½, or effective pressure by the mercurial-gauge 58 lbs. per square inch. The velocity of 20 miles per hour for the first four quarters of a mile of the inclined plane, was reduced to 10 miles for the fifth quarter, and to 6 miles for the following one; afterwards the speed fell completely, on arriving at the steep part that exists towards the top of the inclined plane. This steep part must however be ascended, before it can be said that the engine has gone up the plane; for the average inclination calculated at $\frac{1}{96}$, comprises equally that part, and if we were to separate it from the remainder of the plane, that remainder would have a less inclination than $\frac{1}{98}$: consequently, the load was too much for the engine with that pressure.

lbs.	
1,915	power.
1,746	resistance, equal to 218½ t. on a level.
166	surplus of the power over the resistance, insufficient to overcome the friction of the engine. We have seen that the friction of this engine, even without any load, amounts to 187 lbs.

XII. On August 4, 1834, the ATLAS, of which the proportions have already been given, with a train of 9 loaded wagons and 7 empty ones, weighing together 38.76 t., and with the tender 44.26 t., could not ascend *Sutton;* the balance being fixed at 55, and marking 57½, or effective pressure 60½ lbs. per square inch in the boiler. That pressure is not sufficient; the engine is ready to stop.

lbs.	
2,323	power.
1,755	resistance, equal to 219½ t. on a level.
568	surplus of the power over the resistance, insufficient to overcome the friction of the engine.

ons, weighing 29.65 t., and tender included 35.15 t. The pressure purposely reduced, stood at 29 by the balance, or 48.5 lbs. by the mercurial-gauge. The velocity of 15 miles an hour for the first mile of the ascent fell to 10 miles for the following quarter, and to 6.6 miles for the last quarter of a mile near the top; average velocity 10 miles.

lbs.
1,565 power.
1,344 resistance, equal to 168 t. on a level.

221 corresponding friction of the engine.

XVI. On August 16, 1834, in the morning, the VESTA, the proportions of which have already been given, ascended *Sutton* with a train of 7 loaded wagons, weighing together 34.43 t., and 39.93 t., tender included; the valve fixed at 20 as a point of departure, on the balance, and blowing at 23¼, or effective pressure per square inch by the mercurial-gauge 57.25 lbs. Velocity at the top of the plane, 2.50 miles (The engine had set off on the plane without impulse or acquired velocity.)

lbs.
1,891 power.
1,543 resistance, equal to 193 t. on a level.

348 corresponding friction of the engine.

XVII. On August 16, 1834, in the morning, the same engine ascended *Sutton* with 8 wagons, weighing 31.95 t., and 37.45 t., tender included; balance fixed at 20, as point of departure, and marking 23½, or effective pressure 58 lbs. per square inch in the boiler by the mercurial-gauge. *Minimum* velocity at the moment of attaining the summit of the plane, 3.25 miles.

lbs.
1,915 power.
1,462 resistance, equal to 182¾ tons on a level.

453 corresponding friction of the engine.

XVIII. On August 16, in the evening, the same engine, the VESTA, ascended *Sutton* with 8 loaded wagons, weighing 27.05 t.,

This experiment and the following one confine the friction of the engine within very narrow limits; that is to say, between 568 lbs. and 616 lbs., and seem to raise that friction very high; but in referring to experiment No. XI, on the friction of the engines without load, we see that at the time those two experiments were made, the engine had been newly repaired, and was not yet working satisfactorily. On August 1, its resistance, without load, had been found to be 194 lbs., instead of 152 lbs., that it was before, a circumstance which we attributed then to the connecting-rods not being properly adjusted; but the defect seems however to have been more vital, and to have rather continued to increase, as, on August 7, the axle of the engine broke.

XIII. At the conclusion of the foregoing experiment, just at the moment the engine was going to stop, the pressure was raised, by means of the spring, to 58¾ by the balance, or 61¾ lbs. effective pressure per square inch in the boiler by the mercurial gauge. With that pressure the ascent was concluded, with a speed of 3.75 miles an hour for the upper part of the plane.

lbs.
2,371 power.
1,755 resistance, equal to 219⅓ tons on a level.

616 corresponding friction of the engine.

XIV. On August 4, 1834, the FURY, cylinders 11 in., stroke 16 in., wheels 5 ft., weight 8.20 t., ascended *Sutton* with a first-class train of 8 carriages, amongst which was an empty truck; weight of the train 32.97 t., and with the tender 37.97 t.; pressure purposely reduced to 33 lbs. by the balance, or 55 lbs. by the mercurial-gauge. Average velocity 13.33 miles, *minimum* velocity 10 miles an hour at the top of the plane.

lbs.
1,775 power.
1,466 resistance, equal to 183¼ tons on a level.

309 corresponding friction of the engine.

XV. On August 15, the LEEDS, cylinders 11 in., stroke 16 in., wheels 5 ft., weight 7.07 t., ascended *Sutton* with 7 wag-

and 4 empty ones, weighing together 7 t. more, the tender making altogether 39.05 t. Balance fixed at 20 lbs. and marking 23 lbs., or effective pressure per inch 56.5 lbs. by the mercurial-guage. Velocity at the most difficult point of the ascent, 17 complete strokes of the piston per minute, or 3 miles an hour.

lbs.	
1,866	power.
1,514	resistance, equal to 189 tons on a level.
352	corresponding friction of the engine.

§ 3. *Table of the Results obtained on the additional Friction of Engines.*

If, amongst the foregoing experiments, we bring together those that have produced results, we get the following table. We have placed in it only those experiments, the velocity of which was not considerable. It is, indeed, clear that the more the velocity was reduced, the nearer the engine was to attain the proposed end, that is to say, to arrive at the *maximum* load it could possibly draw with its pressure :—

EXPERIMENTS ON THE FRICTION OF LOADED LOCOMOTIVE ENGINES.

Number of the experiment.	DATE.	Name of the engine.	Diameter of the cylinder.	Stroke of the piston.	Diameter of the wheel.	Weight of the engine.	Friction without any load.	Effective pressure in the experiment.	Velocity of the experiment.	Load on a level.	Corresponding friction of the engine.	OBSERVATIONS.
	1834.		inches.	inches.	feet.	tons.	lbs.	lbs. per square inch.	miles an hour.	tons.	lbs.	
I - -	July 22	VULCAN	11	16	5	8.34	136	57.5	7.50	188	350	
II - -	July 22	—	11	16	5	8.34	136	57.5	12.00	186	367	
VI - -	July 24	FURY	11	16	5	8.20	109	65.5	3.33	244	163	
XIV -	Aug. 4	—	11	16	5	8.20	109	55.0	10.00	183	309	
XV - -	Aug. 15	LEEDS	11	16	5	7.07	108	48.5	6.60	168	221	
XVI -	Aug. 16	VESTA	$11\frac{1}{8}$	16	5	8.71	187	57.25	2.50	193	348	
XVII -	Aug. 16	—	$11\frac{1}{8}$	16	5	8.71	187	58.0	3.25	183	453	
XVIII -	Aug. 16	—	$11\frac{1}{8}$	16	5	8.71	187	56.5	3.00	189	352	
III - -	July 23	ATLAS	12	16	5	11.40	152	55.0	3.50	240	190	
IV - -	July 23	—	12	16	5	11.40	152	53.5	9.23	196	490	
V - -	July 23	—	12	16	5	11.40	152	55.0	6.00	199	517	
X - -	July 31	—	12	16	5	11.40	152	51.0	7.50	202	339	
XIII -	Aug. 4	—	12	16	5	11.40	194	61.75	3.75	219	616	The cnonecting-rods keyed too tight.
		Mean					151			200	362	

Considering the average friction deduced from these experiments, we see that a load of 200 t. causes in the engine, above its proper resistance, an *additional* friction of 362 lbs. 151 lbs. = 211 lbs.; which makes 1.05 lbs., or about 1 lb. per ton.

§ 4. *New Illustration of the Mode of Calculation employed.*

The friction of the engines must be increased by the load; for it is a principle in statics, easy to be ascertained in a simple machine like the lever, the pulley, the winch, &c., that for two forces to equilibrate on that machine, the fixed axis, plane or fulcrum, must support the resulting effort of the two forces. Thus the pressure on the fulcrum is in ratio to that resulting force. If the machine be in motion, we have seen that, as soon as that motion becomes uniform, the power equilibrates exactly the resistance, or the machine falls into the preceding case. Thus again, the pressure on the fixed points is in proportion to the forces that equilibrate on the machine. Consequently, the friction follows the same rule, being itself in proportion to the pressure.

This is applicable to the friction on all the joints of an engine, and consequently to what we call its resistance, which is nothing else than the aggregate of all those frictions.

An increase of resistance, in proportion to the load, is therefore founded on principle, and the mode of calculation we have employed must give us its exact measure. It is sufficient for it that the engine have really attained the limit of its power with a given pressure; that is to say, the *maximum* load it is able to draw with that pressure. In those cases in which the engine reduced its velocity to the rate of two or three miles an hour, it was evident that that point was attained, as the engine was literally going to stop. But besides, we shall see that in all the cases where the velocity did not exceed 12 miles an hour, we were authorised also to consider the pressure on the piston as equal to that in the boiler.

In fact, the steam being at a certain degree of pressure in the boiler, passes into a narrow steam-pipe, and from thence into the cylinder, where it immediatety dilates, and would quickly attain the same degree of pressure as in the boiler if the piston was immoveable. However, the piston opposing on the contrary only a limited resistance, determined by the load drawn by the engine, 40 lbs. per square inch for instance, will obey as soon as the elastic force of the steam in the cylinder will have attained that point. A piston which only bears a resistance of 40 lbs. per square inch, is nothing but a valve loaded with 40 lbs. per square inch. If the communication between the boiler and the cylinder were completely free, and without pipe or narrow passage, the piston would become a real valve for the boiler; and that valve giving way before the safety valve, which is loaded, for instance, with 50 lbs. per square inch, the steam in the boiler could not rise above 40 lbs. The passage, however, being narrowed, the piston is not a valve for the boiler, but it remains one for the cylinder.

From this result three points. 1st. That the pressure in the cylinder is exactly equal to the resistance on the piston. 2nd. That it is because the piston yields and gives way to the steam that the steam cannot augment its pressure beyond that point, nor rise to the pressure in the boiler; but that if by any means the piston could be rendered immoveable, or only if it were not to give way quicker than the steam is generated, the equilibrium of pressure would immediately be established between the cylinder and the boiler; and, 3d., that if, in the steam-pipe, the velocity of the current is greater than the one corresponding to the generation of the steam in the boiler, it is because the pressure is less in the cylinder than in the boiler, and that in consequence the fluid endeavours to put itself in equilibrium in the two vessels; without which there could only be the current, owing to the generation of the steam.

From these observations, we see that the effective pressure on the piston may be calculated after that which exists in the boiler, as soon as the velocity of the piston is reduced to an equality with that of the generation of the steam. As we shall soon know by experience what is the total mass of steam, at the pressure of the boiler, generated by the engine in a given instant, it will be easy to calculate how many cylinders full of steam, at that pressure, the engine is able to furnish in a minute, and thus what is the velocity that corresponds to what

we call full pressure in the cylinders. We shall then find, that for the engines we are examining, that velocity is at least twelve miles an hour. Thus we may consider that in all the cases in which the velocity did not exceed that rate, the pressure in the cylinder was the same as in the boiler, and, consequently, that in reckoning it in that proportion, we had the exact measure of the power then applied by the engine.

CHAPTER V.

GENERAL THEORY OF THE MOTION OF LOCOMOTIVE ENGINES.

ARTICLE I.

OF THE VELOCITY OF THE PISTON.

In endeavouring to calculate the effect of steam engines, that is to say, the velocity of the piston under a given load, the calculations have until now rested on two *data*, the pressure of the steam in the boiler and the resistance of the load on the piston; one being considered as representing the power exercised by the engine, and the other the resistance opposed by the load.

This mode appears exact at first sight, and seems to embrace all the *data* of the problem; but the mistake committed in that respect ought to have been discovered, since every formulæ obtained in that way is easily demonstrated false by experience.

It is particularly when we wish to apply that mode or those formulæ to that motion of locomotive engines, in order to calculate what load they are able to draw at a given velocity, or what velocity they will acquire with a given load, that we discover the formulæ give no rational result.

The cause thereof resides in the following fact, viz. that the pressure of steam in the boiler is by no means the *complete* expression of the power of the engine. It only indicates that power for a determined instant. It is indeed sufficient whenever it is required to compare the effort applied with the effect produced, during a very short instant, or in a case of equilibrium; but as soon as we have a continuation of motion, the pressure in the boiler is no longer sufficient to represent the power of the engine. This is nothing more than what is observed continually in mechanics. In a case of equilibrium, the measure of a force is the mass with which it equilibrates; but in a case of motion, the force is represented not only by the mass it sets in motion, but also by the velocity it is able to impart to that mass. In other words, the force is represented by its own intensity added to the velocity with which it is able to keep up that intensity. The same thing occurs here. The pressure in the boiler indicates the mass with which the engine can equilibrate; but it is the velocity of generation of the steam that indicates the motion the engine is able to impart to that mass.

It is, in fact, evident that the power of the engine resides at the same time, both in the greater or smaller quantity of steam generated, and in the degree of pressure or elastic force of that steam. The power consists thus in the quantity of water the engine is able to transform into steam in a given time, for instance in a minute, which we shall call the evaporating power of the engine, and in the degree of pressure of the steam.

In that valuation we see that the pressure is only the means by which to ascertain the state or intenseness of the power, at the moment its quantity is measured; and this explains the reason why, when the motion is not to last, and that in consequence the quantity need not be considered, the pressure is sufficient to represent the power. But this is not the case in a continued motion.

When an experiment is to be made with an engine, however weak it may be in regard to evaporating power, it will be easy, by charging the valve with 50 lbs. per square inch, to fill the boiler with steam at that effective pressure. If then we attach to the engine a load of 100 t. which would produce, by supposition, on the piston, a resistance of 46 lbs. per square inch, atmospheric pressure included; shall we say that the engine must necessarily draw that load with a certain fixed speed, which will only depend on the pressure of steam in the boiler and the resistance on the piston? No, assuredly. For if it should happen that the engine transform in a minute a cubic foot of water into steam at the pressure of the boiler, it may by that evaporation suffice to produce a certain speed; but

if, all things remaining the same, it only evaporates half the quantity, it is clear that it will only be able to fill the cylinder half as many times in a minutes, and that consequently the pressure in the boiler may remain strictly the same, whilst the speed of the engine with the same load will necessarily be reduced to one half. We see, thus, that neither the pressure in the boiler, nor the supposition that that pressure be maintained in the same state in the different cases of motion, are sufficient to represent completely the power of the engine.

It is thus the evaporation of which the engine is capable that rules its effect, and which must consequently give us the measure of that effect.

If, by analogy with other boilers already tried, and by a comparison of the extent of the heating surfaces, we calculate beforehand what mass of steam a boiler is able to generate in a minute, at a given pressure, we shall then begin to get an idea of the power of which it disposes, and which the engine is able to carry into action.

If, better still, we fill the boiler with water, and produce by some manner or other, in the fire place, a fire as intense as it generally is when the engine is at work, so that we may thus ascertain its evaporating power, then only shall we know what the engine, to which we may join that boiler, will be able to execute in a given time.

The pressure in the boiler, taken by itself, can only solve one of the questions we have to consider: that is to say, the greatest load the engine is able to draw, on account of the necessity which exists that the resistance on the piston should never exceed the pressure in the boiler, as in that case the resistance would be greater than the moving power and no motion would be generated. But, that one case excepted, we must necessarily have recourse to the evaporating power, the pressure being only one of the elements of the force which is to be computed. The separate influence of each of those two elements in the result is as follows:—

The greatest possible load is marked by the degree of pressure in the boiler.

And the greatest speed with that load, or with any other, is given by the evaporating power.

It is therefore by employing both these elements that we shall be able to solve the question.

With that view we shall successively consider three different points.

The resistance produced on the piston by a given load;

The pressure of the steam in the cylinder in consequence of that resistance;

And, finally, the determination, by experiments of the evaporating power of the engines.

These foundations once established, the effect of an engine may easily be calculated by comparing the force of traction the load requires, which fixes the power the engine must expend, with the mass of power of which it is able to dispose; that is to say, its evaporating power.

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ARTICLE II.

OF THE RESISTANCE ON THE PISTON OWING TO A GIVEN LOAD.

We have already explained that when a load is attached to an engine, the *total* resistance which is opposed to the motion of the piston is composed, 1st, of the resistance of the load; 2nd, of the resistance of the engine; 3d, of the atmospheric pressure. By the same reason the *real* elastic force of the steam is not expressed by its effective pressure, but by its *total* pressure.

In the calculations we have hitherto made, having only to compare the power with the ressitance in cases of equality or equilibrium, and without admixture of any other consideration, were at liberty to deduct on both sides an equal quantity, that is to say, to take into account only the effective pressure, and the effective resistance. But now we shall have to consider the steam in regard to its volume; and, that volume being determined by the *total* pressure, we must keep that expression of the elastic force as well as the one which corresponds with it for the resisting force.

Thus the resistance on the piston is composed of the three resistances, of the load, the engine and the atmosphere. Of these three forces, that which is owing to the atmospheric pressure is exerted immediately and directly on the piston. It must therefore be moved with the same velocity as the piston itself. But with the two others it is different. We have already

seen that, in a machine, the pressures produced on different points are in an inverse ratio to the velocity of those points. Here, the engine and its train require to be moved with a velocity greater than that of the piston, in the proportion of the circumference of the wheel to twice the length of the stroke. The intenseness of the pressure produced on the piston, by the resistance of the load and that of the engine, is therefore greater than those same resistances in the above-mentioned proportion of the velocity of the wheel to that of the piston.

Supposing M to represent the number of tons composing the total load, tender included, and n the resistance per ton, nM will be the resistance of the train. If besides F expresses the friction or resistance of the engine without load, and δ the additional friction per unit of load, $F + \delta M$ will be the friction of the engine at the moment it draws the load M.

Thus,—

$$F + \delta M + nM$$

will be the resistance opposed to the progress along the rails by the engine and its train.

This force producing on the piston a resistance augmented in the proportion of the circumference of the wheel, to twice the stroke of the piston, if D be the diameter of the wheel, l the length of the stroke, and π the ratio of the circumference to the diameter,

$$(F + \delta M + nM)\frac{\pi D}{2l}$$

will be the resistance on the piston owing of that force; that is to say, to the friction to the engine and its train.

In the same way, representing by d the diameter of the cylinder, $\frac{1}{2}\pi d^2$ will be the area of the two pistons, and

$$\frac{(F + \delta M + nM)\frac{\pi D}{2l}}{\frac{1}{2}\pi d^2},$$

or

$$(F + \delta M + nM)\frac{D}{d^2 l}$$

will be the same force divided over the piston per unit of surface.

Adding to it, therefore, the atmospheric pressure per unit of surface, which we shall represent by ρ, we shall finally have, for the total pressure, owing to the resistance,

$$R = (F + \delta M + nM)\frac{D}{d^2 l} + \rho.$$

In this equation M is the weight of the load in tons, n is equal to 8 lbs. and $\delta = 1$ lb. D, l and d are expressed in inches, F and ρ in pounds; thus the value of R, when found, is the pressure resulting on the piston, in pounds per square inch.

The quantities D, l and d might also be expressed in feet, and ρ in lbs. per square foot. In that case, the value of R, when found, will be the pressure per square foot on the piston. This way of expressing the resistance comes exactly to the same as the preceding one, and is sometimes more convenient for calculation.

Applying this to a load of 100 t., drawn by an engine with cylinders of 11 in. diameter, stroke 16 in., wheel 5 ft., friction 110 lbs., we have,—

100 × 8 lbs. = 800 lbs. resistance of the train in lbs.
110 lbs. friction of the engine without load.
100 lbs. additional friction, owing to the load.

1010 lbs. total resistance to the progressive motion of the wheels.

3.1416 × 60 in. = 188.50 in. cirumference of the wheel expressed in inches.

2 × 16 in. = 32 in. double of the stroke.

$\frac{188.5}{32} = 5.887$, ratio of the velocity of the wheel and of the piston.

Thus 1010 lbs. + 5.887 = 6,946 lbs. resistance produced on the piston.

Besides $\frac{3.1416 \times 11^2}{2} = 190$ in. area of the two pistons in square inches.

Thus $\frac{5946 \text{ lbs.}}{190} = 31.2$ lbs. resistance on the piston, divided over

each square inch of its surface.

And, lastly 31.2 lbs. + 14.7 lbs. = 46 lbs. final resistance per unit of surface of the piston of an engine with cylinders of 11 in. diameter, &c. drawing a load of 100 gross tons, tender included.

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ARTICLE III.

OF THE PRESSURE IN THE CYLINDER.

The resistance on the piston being known, we may deduce from it the pressure of the steam, at the instant it acts as a moving power in the cylinder. It is sufficient for that to observe what passes during the motion.

The steam, being at first shut up in the boiler at any degree of pressure, passes into the steam-pipes and from thence into the cylinders. When it arrives in those cylinders, the area of which is about ten times as great as that of the pipes, the steam must necessarily expand and lose in the same proportion of its elastic force. However, the piston is still immovable; so that the steam continuing to arrive rapidly, the equilibrium of pressure is quickly established between the boiler and the cylinder. The pressure then becomes the same in the two vessels, and the piston being impelled by the force of the steam, begins slowly to move. The motion is communicated to the engine and to its whole train, and the mass gets a certain speed. This acquired speed continuing a little longer than the cause which produced it, the consequence is, that, at the following stroke, the steam finds the piston already slowly driven in a retrogade direction, at the moment when it gives it a fresh impulse, which in its turn is communicated to the total mass, where it continues to accumulate. Thus, receiving at each stroke a fresh impulse, while it still keeps the preceding one, the piston accelerates, by degrees, its speed, and the train finally acquires all the velocity the engine is able to communicate to it.

We have said that, at the beginning of the motion, an equilibrium of pressure is established between the boiler and the cylinder; but, in proportion as the velocity of the piston increases, this piston recedes, in a way, before the steam, without giving it sufficient time to establish the equilibrium, so that the pressure in the cylinder must necessarily diminish.

Nevertheless, the increase of the velocity and the diminution of the pressure have their limits. It is observed in every machine that the speed, at first very small, increases by degrees, as we have said, but only to a certain point which it never passes, the moving power not being capable of a greater speed with the mass to be moved. If the machine is well constructed, and particularly if it is regulated by a fly-wheel, the velocity once acquired is maintained without alteration, although the action of the moving power may continue to vary or to oscillate between certain limits, and the motion becomes perfectly uniform.

In the engines we consider, the mass of the train itself acts the part of a fly-wheel. That mass receives and stores up, in a manner, the additional velocity produced by the moving power at the time of its greatest action, in order to refund it afterwards, whenever the moving power happens to be in a moment of less force. It is from the difficulty of increasing and also of diminishing the speed of the mass, that the uniform motion results.

In regard to certain points of the engine, which, like the piston for instance, must necessarily vary in velocity during their oscillations, the uniformity of which we are speaking, consists in an exact periodical motion, which causes the velocity at each point of an oscillation to be precisely the same as it was at the same point of the preceding one. The result of this is, that if we take the duration of one of these oscillations as the unit of time, the motion will be strictly uniform.

As soon as the motion has acquired uniformity, which always takes place after a very short time and which is the regular state of the engine while travelling, the moving power, which at the beginning of the motion, was obliged to make an effort necessarily greater than the resistance, needs at present only to expend a force just sufficient to keep the resistance in equilibrium. For, if the moving power were to apply a greater or smaller force, the motion would be either accelerated or retarded, whilst, in fact, it is uniform.

From that moment, consequently, the

pressure of the steam *in the cylinder*, which is the effort applied by the moving power, must be equal to the pressure of the resistance against the piston, which is the effort made by the resistance. This principle has been already demonstrated less extensively in another place.

We know thus the pressure at which the steam is expended by the cylinder, and as we also know the volume of the cylinder, we shall be able from both to conclude the absolute expense of power which takes place at each stroke of the piston. It is that expense, which, compared with the total mass of steam of which the engine can dispose, will give us, without any difficulty, the means of determing the velocity of the motion.

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ARTICLE IV.

OF THE EVAPORATING POWER OF THE ENGINES.

§ 1. *Experiments on the Evaporating Power of the Engines.*

We have yet to determine the chief element of the question, viz. the evaporating power of the engines or the quantity of water they are able to transform into steam, under a determined pressure, in a given time.

With that view we undertook a series of experiments on the quantity of water evaporated by the engines of the Liverpool and Manchester Railway, during their journey from one of those towns to the other.

All the tenders on that Railway having exactly the same dimensions and an uniform shape, one of them was weighed, first empty and then loaded, whereby was ascertained that every inch of water in the task corresponded exactly with a weight of 206.5 lbs. Then we proceeded in the following manner:—

We first ascertained, by means of the glass tube, at what height the water stood in the boiler at the moment of starting; and then we also measured the exact height of the water in the tender. At the end of the journey, or at the intermediate station, if the engine stopped to take in fresh water, we first filled the boiler to the same height where it stood before setting off, and then we measured the water remaining in the tender. The difference between the height in the tender gave the consumption of water during the journey.

When describing these experiments, in order that the reader may see at once before him all the elements that have any importance in the question, we shall give the load of the engine, the time it took to complete the journey, which shows the velocity, the distance being 29½ miles, the state of the spring-balance from which the pressure results, and finally the temperature of the water in the tender at the moment of starting. We shall explain hereafter the column containing the total rising of the valve, which would permit all the steam generated in the boiler to escape.

EXPERIMENTS ON THE EVAPORATING POWER OF THE ENGINES.

Number of the experiment.	DATE.	Name of the engine.	Load of the engine tender included	Water evaporated.		Total duration of the journey.	Delays on the road included in that time.	Average state of the spring-balance.	Rising of the valve sufficient to give issue to all the steam generated in the boiler.	Average effective pressure during the experiment in lbs. per square inch.	Temperature of the water in the tender at starting.	Velocity of the engine in miles per hour.	Evaporation per hour in each experiment.	Heating surface.	
				In lbs.	In cubic feet.									Exposed to the action of radiating caloric.	Exposed to the action of communicative caloric.
	1834.		tons.	lbs.	cubic ft.	hours.				lbs.		miles.	cubic ft.	sq. feet.	sq. feet.
I - - -	July 22	VULCAN	39.07	4646	74.34	1.17′	3′	31...32.5	5	54.5	just lukewarm	22.99	57.92	34.45	307.38
II - -	July 23	ATLAS	195.50	8260	132.16	3.17	15	50...50.7	4	53.7	cold	8.99	40.25	57.06	217.88
III - -	Aug. 4	—	127.64	5937	94.99	1.58	0	50...50.1	4	53	cold	15.00	48.30	—	—
IV - -	July 31	—	40.15	5524	88.38	1.54	0	24...25.5	4	30	cold	15.53	46.52	—	—
V - -	July 24	FURY	56.16	4878	78.05	1.30	0	31.2...32.6	5	57	cold	19.67	52.03	32.87	307.38
VI - -	July 24	—	48.80	5446	87.14	1.35	0	31.2...32.7	5	57	cold	18.63	55.03	—	—
VII -	July 26	FIREFLY	41.40	6143	98.29	1.40	5	14.5...14.5	3	44	almost cold . .	17.70	58.97	43.91	362.60
VIII -	July 26	—	41.40	6040	96.64	1.23	5	16.6...17.3	3	49	lukewarm . .	21.33	69.86	—	—
IX - -	Aug. 1	VESTA	33.15	4130	66.08	1.5	0	20. ...21.3	3.5	51	very hot . . .	27.23	61.00	46.00	256.08
X - -	Aug. 15	LEEDS	88.34	5989	95.82	1.35	0	31. ...32.2	5	54	just lukewarm	18.63	60.52	34.57	307.38
XI - -	Aug. 15	—	37.51	5317	85.07	1.20½	3	26.5...28.5	5	49	very hot . . .	21.99	63.41	—	—
											Means - - - - - -	18.88	55.82	43.12	288.35

In those experiments, we have mentioned the state of temperature of the water in the tender, because that circumstance must more or less facilitate the generation of steam, as it is easier to bring to the boiling point water already warm than cold water. However, as the temperature we mark in the tender, exists only at the moment of starting, and as it can remain thus only during a very small part of the journey, which lasts an hour and a half to two hours, it really has but a very inconsiderable influence on the result, of which the above experiments are, besides, sufficient proof.

We have also set down the pressure under which the steam was generated in each experiment. Water not being able to evaporate under a high pressure, unless by means of a higher temperature, we have reason to suppose that, *cæteris paribus*, the engine must be able to evaporate less water under a more considerable pressure. But as we shall see below, in a table we shall give on the volume and temperature of the steam, that between the degrees of pressure at which the engines constantly work, viz. between 50 and 60 lbs. effective pressure per square inch, the difference of temperature is only nine degrees by the thermometer, or 4½ degrees difference for the mean pressure, we shall easily be convinced that the influence of the pressure on the quantity of water evaporated must be almost imperceptible. Besides, when we employ a less elevated pressure, the steam generated under that pressure occupies more space, the boiler is too small to contain it, and the valve is consequently more subject to blow. The result is, that the engineman accustomed to regulate himself by the valve, seeing it continually blow, does not animate his fire so much as in the case where the valve is fixed at a higher pressure. The circumstance, therefore compensates for the former one, and frequently surpasses it.

We see, consequently, in the related experiments, that the speed is the only thing that has a constant and perceptible effect on the generation of steam.

The cause of this effect of the speed is, that in those engines the steam, in issuing from the cylinders, is conducted to the chimney, where it creates an artificial current of air, and acts exactly in the same manner as the bellows in giving activity to the fire. Every jet of steam represents a stroke of the bellows; and it is consequently clear, that the more rapid the motion of the engine, the more cylinders of steam will be thrown into the chimney in a minute, and the more violently also will the fire be excited.

By examining the experiments, we find, in fact, that the greater the velocity of the motion, the more considerable was the evaporation; and for that reason it is necessary, in endeavoring to determine the evaporating power of the engines, to take them at their average velocity.

The speed of 18½ miles per hour, which is the average speed of our experiments, fulfils tolerably well that condition for the Liverpool engines. We must, therefore, consider the corresponding evaporation, which was equal to 55.82 cubic feet per hour, as the average evaporation of the engines employed.

Nevertheless, we see that some of those engines have evaporated 60 or 62 cubic feet of water per hour, which makes a cubic foot per minute, or a pound of water per second.

§ 2. *Of the evaporating Power per unit of heating Surface.*

However, as the different engines that figured in the experiments differed in regard to their heating surface, we can determine precisely the evaporating power only, by comparing the effects of evaporation with the dimensions of the surface which produces them.

That is the object of the two last columns we added to the preceding table, which repeat the dimensions of the heating surfaces of the engines, so as they were given with more particulars in our first chapter (Chap. I. Art. II. § 3.)

By the mean results of those two columns we see that the average evaporation of 55.82 cubic feet of water, was produced by a heating surface consisting of 43.12 square feet exposed to the action of the radiating caloric, and 288.35 square feet exposed to the communicative heat. This is, therefore, the extent of evaporating surface to which we must refer the effect produced.

If we admit, in consequence of the experiment related in our first chapter (Chap.

I. Art. II. § 3,) that each unit of surface exposed to the communicative heat produces the third part of the effect that same surface would produce if exposed to the radiating caloric, the heating surface above may be represented by 139.24 square feet exposed to the immediate or radiating action of the fire; and as those 139.24 square feet have produced in an hour the evaporation of 55.32 cubic feet, we see that each square foot has evaporated a volume of water expressed by 0.401 cubic foot.

Thus at a velocity of 18½ miles per hour, which is nearly the average speed of the engines, each square foot of heating surface, exposed to the radiating action of the fire, evaporates in an hour a volume of water of 0.401, or a little more than $\frac{4}{10}$ of a cubic foot. This is the expression of the *evaporating power of the engines per unit of heating surface.* Multiplying this, for each engine, by the extent of the heating surface, we shall find the total evaporating power of the engine.

§ 3. *Of the effective evaporating Power of the Engines.*

We must however remark, that although all that water is transformed into steam, there is only a part of it applied to the working of the engine. To be convinced of this fact, we need only examine the valves of the engines while working. We see them constantly emit a considerable quantity of steam, which, instead of entering the cylinders, escapes immediately into the atmosphere. This loss is a defect which it would perhaps not be difficult to correct, and, if corrected, would tend considerably towards an economy of fuel.

The plan in contemplation on the Liverpool Railway of replacing the present cylinders of the engines by others of a greater diameter, will at least have that advantage, that in case of considerable loads, it will render available all the steam generated in the boiler.

In the experiments of which we have given an account, not only is that loss perceptible, but it is even susceptible of being to a certain degree appreciated.

Under the head "*State of the Spring-balance,*" we have inscribed in the table above according to the observation in each experiment, the point of departure of the spring-balance, and the point at which it rose by blowing. The interval between these two degrees gives the rising of the valve that took place during the experiment, to which rising was owing the escaping of the steam. Thus, in the first experiment, the valve of the VULCAN fixed at 31 as point of departure, rose to 32½ by the blowing; consequently, the rising of the valve was of 1½ degree on the balance. The same for the others.

In the following column we have given the quantity of rising sufficient for the valve of each of the engines to give issue to all the steam the engines are able to generate. This point may have been already observed in our experiments on the pressure. We have seen, that whatever care be taken to animate the fire, the valve can never rise beyond a certain point, because then it gives issue to all the steam generated. An exact knowledge of this point was easy to acquire by observation in the numerous experiments on the velocity of the engines we are going to relate.

Thus we found, for instance, that the ATLAS engine, travelling at its greatest speed, and stopped all of a sudden, at the instant it was generating the most steam, raised its valve from 50 degress to 54 degrees; and that the passage resulting from that rising was sufficient to evacuate all the steam. In the same manner, the LEEDS, VULCAN, and FURY, raised in similar circumstances their valve from 31 to 36, VESTA from 20 to 23½, and FIREFLY from 17 to 20; the second valve of these engines being, besides, at the points indicated for them in our experiments on pressure. These degrees of rising naturally depend, 1st, on the quantity of steam generated by each engine, and the diameter of the valve; 2nd, on the dimensions of the levers and the size of the divisions of the balance, which makes a degree by the balance correspond with a greater or a lesser rising; and, lastly, on the second valve, which may give more or less issue to the steam.

These circumstances explain the differences that appear to exist between the engines. In the ATLAS, the second valve gave no issue to the steam, and the first was only 2½ in. in diameter; but the divisions of the balance of that engine being very great, on account of the proportions of the lever, four divisions of the balance

are equal to a considerable rising of the valve, which was sufficient to evacuate the steam. In the LEEDS, VULCAN, and FURY, the second valve did not rise in the pressures we employed; but the first valve, which is the one we consider here, was 3 in. in diameter. In the VESTA, the second valve gave issue to the steam as well as the first; the consequence of which was, that a rising of 3.5 degrees of the balance was sufficient for the evacuation of the steam. Lastly, in the FIREFLY, only one of the valves blew, but at the time of the experiments that engine was in a very bad condition. Its boiler was leaky, the water ran out into the fire-place, where it evaporated, and a very small quantity of steam was really collected in the boiler.

Repeated experiments having, therefore determined these points in a positive manner, it now becomes possible, with the elements we have at our disposal, to appre, ciate the quantity of steam that escaped during the above-mentioned experiments. It is sufficient for that to compare the two columns, one of which shows the rising that really took place, and the other the rising that would have been sufficient for the evacuation of all the steam. By that means, we shall find that the average rising that took place during the experiments was 12 on 46.5. A quarter of the steam was, therefore, lost through the valve—we might even say a little more, particularly considering that the FIREFLY engine was then in a bad condition—and lost some of its steam through the leaks of its boiler.

On the other hand, that loss of steam is not accidental, but inherent to the construction itself of those engines; and among all the experiments on the velocity that we shall relate below, there will scarcely be found a single instance in which that effect was not produced; and when it was not, the reason was that the fire was not excited to the highest possible degree. It is therefore necessary to establish a distinction between the evaporating power of the engine, and what we shall call their *effective* evaporating power; that is to say, the part of that power which is really applied to the working of the engine.

From the experiments above, we find that of all the steam generated in the boiler, three quarters only enter into the cylinders.

Thus, the evaporating power per square foot of heating surface exposed to the radiating caloric, having been found to be 0.401 cubic foot, the available part of it, or the *effective evaporating power expressed in cubic feet of water evaporated in an hour per square foot of surface, is* 0.301 *cubic foot, or* $\frac{3}{16}$ *of a cubic foot.*

Finally, returning to the mean of the above experiments, the evaporating power was in each hour 55.82 cubic feet; consequently, the *effective* evaporating power, taken as an average for all the engines, is 41.87 cubic feet.

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ARTICLE V.

OF THE PROPORTIONS OF THE ENGINES, AND THEIR CORRESPONDING EFFECTS.

§ 1. *Analytical expression of the Velocity of the Engine with a given Load.*

With these elements it is easy to determine the velocity which an engine is able to acquire with a given load.

Supposing, for instance, we have a load of 100 t., tender included, attached to an engine with cylinders of 11 in. diameter, stroke 16 in., wheels 5 ft., friction 110 lbs., *effective* pressure of the steam in the boiler 50 lbs. per square inch, and finally effective evaporating power, such as we have found it for the average of the Liverpool engines, that is to say, 41.87 cubic feet of water evaporated in an hour.

We have already seen above (Chap. V. Art. II.,) that the *total* resistance which that load opposed to the motion of the piston in the case of that engine was 46 lbs. per square inch; and we have also seen that, in consequence of that resistance, the total pressure of the steam, when arriving in the cylinder, was also necessarily 46 lbs. per square inch.

The mass of water evaporated is 41.87 cubic feet per hour, or 0.70 cubic feet per minute. This water is immediately transformed, in the boiler, into steam, at the effective pressure of 50 lbs. per square inch or at the total pressure of 65 lbs. per square inch.

But we know the volume of the steam generated under a determined pressure. Tables of that volume have been formed from experiment, and one will be found below, § 11. According to these tables, the

steam, generated under a total pressure of 65 lbs. per square inch, occupies 435 times the space of the water which produced it. Thus the water transformed into steam at the total pressure of 65 lbs. per square inch, and spent each minute in the motion, formed a volume of

$$0.70 \text{ c. ft.} \times 435 = 304 \text{ cubic feet.}$$

This steam, penetrating into the cylinders, is then reduced to a pressure of 46 lbs. Its temperature, however, remains the same, because the pipes that conduct it to the cylinders and the cylinders themselves are immersed in the boiler, or surrounded by the flame that comes out of the fire-place. We know that the space occupied by the steam, when its temperature remains the same, augments in an inverse ratio to the pressure. At the moment it arrives in the cylinders, that same mass of steam occupies consequently a greater space in the proportion of 65 to 46.

Thus its total volume is then

$$304 \times \frac{65}{46} = 430 \text{ cubic feet.}$$

Now, the area of the two cylinders is 190 square inches or 1.32 square foot; thus the above volume of 430 cubic feet of steam, passing through the cylinders in a minute, must necessarily cross them with a velocity of

$$\frac{430}{1.32} = 326 \text{ feet per minute.}$$

which gives us, consequently, the velocity of the piston in feet per minute with the supposed load.

To deduce from that the speed of the engine in miles per hour, we must observe that an hour contains 60 minutes, and thus that the speed per hour will be 60 times as great; a mile containing 5280 ft., the produce must be divided by that number in order to have the speed expressed in miles; and finally the speed of the engine, according to the proportion of the stroke to the diameter of the wheel, is 5.887 times that of the piston.

We shall consequently have

$$\frac{326 \times 60}{5280} \times 5.887 = 21.83 \text{ miles, velocity of}$$

the engine per hour.

Thus we see that the evaporation supposed above, must necessarily produce a velocity of 21¾ miles per hour for the engine; that is to say, that a locomotive engine, with the above-mentioned proportions, is able, if in a good condition and with a well-animated fire, to draw a load of 100 t., tender included, with a velocity of $21\frac{3}{4}$ miles an hour.

The same mode of calculation may serve for any other load or any other engine. Thus, in general, making again use of the letters already employed in our research of the resistance on the piston, viz.

M representing the number of tons of the load.

n the resistance of the load per ton.

F the friction of the engine without load.

δ its additional friction for each to of the load.

D the diameter of the wheel.

d the diameter of the cylinder.

l the length of the stroke.

And ρ the atmospheric pressure per unit of surface.

$$R = (F + \delta M + nM)\frac{D}{d^2 l} + \rho,$$

will be the pressure of the steam per unit of surface in the cylinder as above demonstrated (Chap V. Art. II.)

If, besides,

P express the total pressure of the steam in the boiler;

s, The effective evaporating power of the engine expressed by the number of cubic feet the boiler is able to evaporate in a minute at the pressure P,

And m the ratio of the volume of steam, at the degree of pressure P, to the volume of water,

$$m \times s$$

will be the total volume of steam generated in a minute at the pressure P of the boiler.

The steam, arriving in the cylinder passes from the pressure P to the pressure R, and changes its volume in an inverse ratio to the pressures; so that

$$ms \times \frac{P}{R}$$

is the space occupied by the steam when arrived in the cylinders.

This volume of steam, crossing the cylinders in a minute, if we divide it by the area of the cylinders, we shall have the speed it must necessarily have, and consequently the velocity it will communicate to the piston.

Now the area of the two cylinders is $\frac{1}{2}\pi d^2$; thus the velocity per minute will be,

$$\frac{ms\,P}{\frac{1}{2}\pi d^2 R}.$$

In order to effect that division, the area of the cylinders ought necessarily to be expressed in units similar to those of the volume *s*. The area of the cylinders must be then expressed in square feet and not in inches; and the same condition is consequently required also for R, P, and ρ. So in the calculation we must express the pressures in lbs. per square foot, which puts them at the same rate as if expressed in the usual manner.

Passing from this expression to the velocity of the engine, we know that it is to the velocity of the piston in the proportion of the circumference of the wheel to twice the stroke, thus the speed of the engine is

$$v = \frac{ms\,P\,D}{R\,d^2\,l};$$

or, putting for R its value found above, and passing from the speed per minute to the speed per hour, in multiplying by 60,

$$V = 60\,\frac{ms\,P\,D}{(F+\delta M+nM)\,D+\rho d^2 l}.$$

It must be remarked that 60 *s* is equal to S, or the evaporating power *per hour*; that is to say, that by employing this value it is no longer necessary to multiply by 60, and the reckoning will be simplified in its application.

The formula will then be,

$$V = \frac{m\,P\,S\,D}{[F+(\delta+n)M]\,D+\rho d^2 l}.$$

This will consequently be the general expression of the velocity of the engine per hour; expression in which everything is known by measures taken on the engine, even the evaporating power S, which results from the extent of the heating surface computed as above. *m*, which is the volume of the steam generated under the pressure P, is found in a table like the one below (Chap. V. Art. V. § 11.)

By means of this formula, and by measures simply taken on the engine, it will therefore be easy to determine immediately the effect we may expect from it.

In that expression, the evaporating power S being expressed in cubic feet the resulting speed will also be expressed in feet. If we wish to have it in miles, as a mile contains 2580 ft., it will be sufficient to divide by that number, and the result will be the speed of the engine in miles per hour.

We shall see further on that the produce *m*P is almost invariable; and consequently we learn by the inspection of this formula, that the velocity of an engine with a given lead increases with the heating surface and the diameter of the wheel, and diminishes, on the contrary, when the diameter of the cylinder and the stroke of the piston augment.

§ 2. *Analytical expression of the Load that an Engine can draw at a given Velocity.*

If, on the contrary, we wish to know the load a given engine can draw at a determined speed, it is sufficient, in the foregoing equation, to consider V as known and to draw from it the unknown quantity M.

It will then be,

$$M = \frac{m\,P\,S\,D - \rho d^2 l\,V}{(\delta+n)\,V\,D} - \frac{F}{\delta+n}.$$

After the manner that the calculation has been established, it is clear that the value we shall find for M, will be the number of tons of the *total* load, that is to say, tender included.

§ 3. *Of the Heating Surface that must be adopted to obtain from an Engine a determined Velocity with a given Load.*

The same equation may also serve to determine any one of the indeterminate quantities in the general problem of locomotive engines. Thus, for instance, it will show the extent of heating surface, or the evaporating power necessary to enable an engine to draw a known load at a fixed speed. For that, we have only to draw from the general equation the value of S.

It will be,

$$S = \frac{V\,[(\delta+)\,M\,D\,n\,F\,D+\rho\,d^2\,l]}{m\,P\,D}.$$

The result thus obtained will be the effective evaporating power of the engine in cubic feet of water per hour; and as we have seen (Chap. V. Art. IV. § 3) that the effective evaporating power is equal to $\frac{3}{10}$ of the heating surface expressed in square

feet, we shall easily obtain the last by multiplying the result by the fractional number $\frac{10}{3}$.

§ 4. *Of the Maximum Load of an Engine with a given Pressure.*

We found above (§ 2) the expression of the load an engine is able to draw at a given velocity; and the less the velocity, the more considerable may be the load. We must, however, add that in all cases, for the motion to be possible, the resistance on the piston must not be greater than the force that is to move it. Consequently, the resistance we have expressed by R must, at most, be equal to P. This observation fixes the limits of the possible load, with a determined pressure. Beyond that point the equation may continue to give results, but they will no longer suit the question. The limit of the load with the pressure P will thus be known by the equation R = P; or,

$$[F + (\delta + n) M] \frac{D}{\rho d^2 l} + \rho = P,$$

which gives

$$M = \frac{(P - \rho) d^2 l}{(\delta + n) D} - \frac{F}{\delta + n}$$

This equation will give the maximum load of the engine, including the weight of the tender, subservient, however, to the conditions of adhesion explained hereafter, in Chap. VIII.

§ 5. *Of the Velocity of the Engine corresponding with the Maximum Load.*

Putting that value of M in the formula that gives the speed, we have the speed corresponding with the maximum load. After the necessary reductions we find—

$$V = \frac{m S D}{d^2 l}.$$

If we write this expression under the following form—

$$V = \frac{m S}{\frac{1}{2}\pi d^2} \times \frac{\pi D}{2l},$$

we shall perceive at first sight, that it is exactly the speed produced by the passage in the cylinders of the steam of the boiler, when that steam undergoes no reduction of pressure. In fact, $\frac{m S}{\frac{1}{2}\pi d^2}$ is the mass of steam produced *at the pressure of the boiler*, divided by the area of the two cylinders; that is to say, the speed which its passage in the cylinders, without alteration, produces for the piston; and multiplying that quantity by $\frac{\pi D}{2 l}$ which is the proportion of the velocity of the engine to that of the piston, the result will naturally be the relative speed of the engine.

We also see that in the case of a maximum load, the pressure of the steam in the cylinder will be the same as in the boiler, and that its velocity will be the very velocity at which the steam is generated in the boiler; results which besides are, of themselves, evident to an attentive mind, and which have already been pointed out.

In regard to the limit of speed with small loads, the engine-men never urge it so as to risk an accident, by too great a velocity in the motion of the piston, or other parts of the mechanism. Only one single instance, in the experiments we shall relate below, will be found, in which the engines attained a speed of 35 miles an hour. This velocity is the greatest that has been observed, until the present moment, except during some extremely short intervals. When the train is too light, the engine-men take care partially to shut the regulator, and not to animate the fire to its highest pitch, as we shall mention hereafter.

§ 6. *Of the Diameter that ought to be given to the Cylinder, to render an Engine capable of attaining a fixed Maximum Load.*

The same equation from which we have concluded above (§ 4) the limit of possible loads with a given pressure, may also serve to determine the diameter that ought to be given to the cylinders of an engine to render it capable of drawing a fixed load at a certain pressure.

$$d = \sqrt{\frac{D [(\delta + n) M + F]}{(P - \rho) l}}.$$

This diameter will be expressed in feet, according to the manner the calculation was made. It will be easily reduced to the common expression in inches.

§ 7. *Of the Length that ought to be given to the Stroke of the Piston of an Engine, the Cylinders of which have already a fixed Diameter, so as to enable that Engine to draw a certain Maximum Load.*

In the same manner, also, if the diameter

of the cylinder has already been chosen on account of some other consideration, we may, in a certain degree, produce the same effect; that is to say, render the engine able to attain the maximum load required, by adopting for the stroke of the piston a suitable length. In that case the equation gives—

$$l = \frac{D\,[(\delta + n)\,M + F]}{(P - \rho)\,d}.$$

This measure of the stroke will be expressed, according to the adopted measures, in feet and decimals of feet; one may transform it, as usual, in inches.

§ 8. *Of the Diameter that ought to be given to the Wheel of an Engine, so as to enable it to draw a fixed Maximum Load.*

We may also obtain the same result by reducing, in a suitable proportion, the diameter of the wheel, by which the speed of the engine will be diminished, and a greater power of traction given to it. The equation will, in that case, give for the diameter of the wheel—

$$D = \frac{(P - \rho)\,d^2\,l}{(\delta + n)\,M + F}.$$

It is understood that this method can only succeed within certain limits, and that the diameter of the wheel cannot be reduced beyond certain dimensions, fixed by the other requisites of the business.

§ 9. *Of the effective Pressure necessary in the Boiler of an Engine, the Dimensions of which are already fixed, in order that the Engine may draw a certain Maximum Load.*

Finally, if the length of the stroke, the diameter of the cylinders, and that of the wheel are already fixed, we may calculate what is the pressure that must be produced in the boiler to enable the engine to attain the maximum load required. The same equation resolved in that case, in regard to the quantity P considered as unknown, gives—

$$P - \rho = \frac{D\,[(\delta + n)\,M + F]}{d^2\,l}.$$

This pressure will be expressed, according to the adopted measures, in pounds per square foot, but, by taking the $\frac{1}{144}$ part of it, we may reduce it to the usual expression of pounds per square inch.

The same would take place in regard to any other research. These deductions are easily found;—we shall not stop any longer on this point. It is scarcely necessary to add, that the values given by those equations are only applicable to the questions, in as far as they are not in opposition to the practical rules of construction. Thus, the pressure determined above must in no case exceed the resistance of which the metal of the boiler is capable; neither must the diameter of the wheel be large enough to put the engine in danger in going off the rails, nor small enough to destroy its speed, &c. &c.

§ 10. *Synoptical Table of the preceding Formulæ.*

In a view to facilitate practical researches, we shall collect here those different forformulæ into a table.

The signs employed having the following significations, viz.:—

M, representing the number of gross tons of the load, tender included.

n, the resistance per ton of the load, or according to the determination already made, $n = 8$ lbs.

F, the friction of the engine without load, taken, according to the average of the above experiments, in case the engine is not yet constructed; that is to say, at 15 lbs. per ton of its presumed weight. In case the engine is already constructed, and one wishes to obtain a very accurate result, F must be determined by a direct experiment made on the engine itself.

δ, the additional friction of the engine per ton of load, or according to the determination hereabove, $\delta = 1$ lb.; and, consequently, $(\delta + n) = 9$ lbs.

D, the diameter of the wheel, expressed in feet.

d, the diameter of the cylinder, also expressed in feet and decimals of feet.

l, the length of the stroke, in feet and decimals of feet.

P, the *total* pressure (or atmospheric pressure included) of the steam in the boiler, expressed in pounds per square foot; that is to say, 144 times the pressure per square inch.

ρ, the atmospheric pressure expressed in pounds per square foot as above, that is to say, $\rho = 2117$ lbs.; and, consequently

$(P - p)$, the effective pressure of the steam in the boiler, being expressed in the same manner, viz., in pounds per square foot.

S, being the *effective* evaporating power of the engine per hour, or otherwise, according to the described experiments, S being the $\frac{3}{10}$ of the number of square feet in the *reduced* heating surface. (It will be recollected, that the *reduced* heating surface itself consists of the sum of the heating surface of the fire-place, more the third part of the heating surface of the tubes.)

m, being the ratio of the volume of the steam at the *total* pressure P, to the volume of water that has produced it, according to the known tables, one of which will be found in one of the following paragraphs.

V, finally, being the velocity of the engine in feet per hour, that velocity being necessarily expressed in that manner for the general harmony of the calculation; but as a mile contains 5280 feet, it can easily be reduced to the speed in miles, and *vice versa*.

These different signs being thus well understood, and the letters *n* and δ being replaced by their values, 8 lbs. and 1 lb., the formulæ above give the following table :—

SYNOPTICAL TABLE OF THE PRACTICAL FORMULÆ OF LOCOMOTIVE ENGINES.

QUESTIONS TO BE SOLVED.	FORMULÆ.
1. *Velocity* which an Engine of known proportions will take, when working at a given pressure, and drawing a determined load. The result being the speed in feet per hour, the speed in miles will be obtained by dividing by 5280 :—	$V = \frac{m P S D}{(F + 9 M) D + \rho d^2 l}$
2. *Load* that a given Engine will be able to draw, with a known pressure, and at a determined velocity. This load will be expressed in gross tons, tender included :—	$M = \frac{m P S D - \rho d^2 l V}{9 V D} - \frac{F}{9}.$
3. *Heating Surface* that must be given to the boiler of an Engine, in order that it may draw a known load with a fixed velocity. The equation gives the effective evaporating power per hour, from which the heating surface may be deduced by multiplying by the fractional number $\frac{10}{3}$:—	$S = \frac{V[(9 M + F) D + \rho d^2 l]}{m P D}.$
4. *Maximum load* that an Engine is able to draw at a determined pressure. This load is expressed in gross tons, and includes the tender :—	$M = \frac{(P - \rho) d^2 l}{9 D} - \frac{F}{9}.$
5. *Velocity* of an Engine, with its *maximum* load. This speed being expressed in feet, the speed per mile will be its $\frac{1}{5280}$ part :—	$V = \frac{m S D}{d^2 l}.$
6. *Diameter* that must be given to the *cylinder* of an Engine not yet constructed, in order that, if necessary, it may draw a certain maximum load. The diameter being expressed in feet and decimals of feet, its expression in inches will be found in multiplying by 12 :—	$d = \sqrt{\frac{D (9 M + F)}{(P - \rho) l}}.$
7. *Length of stroke of the Piston* that may replace the diameter of the cylinder and produce the same effect of maximum load. This stroke will be expressed in feet, and may be transformed into inches, as above :—	$l = \frac{D (9 M + F)}{(P - \rho) d^2}.$
8. *Diameter of the wheel* of an Engine, in order to render it able to draw the same maximum load :—	$D = \frac{(P - \rho) d^2 l}{9 M + F}.$
9. *Effective pressure* that must be produced in the boiler of a given Engine, in order to render that Engine capable of drawing a certain maximum load. This pressure being expressed in pounds per square foot, the pressure per inch will be its $\frac{1}{144}$.	$(P - \rho) = \frac{D (9 M + F)}{d^2 l}.$

We must remark that these formulæ are not such as are called *empiric* ones; that is to say, imaginary suppositions, corresponding more or less exactly with experience. They are, on the contrary, rigorous deductions from the most solid principles of mechanics; their elements have been determined by direct experiments, and their results will soon be confirmed in the same way.

In all cases, these formulæ suppose the engine drawing its load *on a dead level*. If it be required to apply them to the case of an inclined plane, it will suffice to take for M, not the nominal load of the engine, but its real load; that is to say, not merely the resistance of the wagons, but their resistance *in ascending the inclined plane in question*, as will be seen in Chap. VII. Art. II.

§ 11. *Table of the Volume of the Steam generated under different degrees of Pressure, necessary for the application of the Formulæ.*

The use of the formulæ we have obtained, necessitating a knowledge of the volume of the steam at different degrees of pressure, we subjoin here a table which we have calcuted from 5 to 5 lbs. pressure. The intermediate degrees may be easily filled up; but it would be an unnecessary operation, as we shall see that the pressure in the boiler has so little influence on the speed, that we may, in our calculations, take from the table the pressure nearest to the one we require, provided we also take the volume corresponding with that approximate pressure.

The reason of the little influence the pressure has on the result is, that in proportion as the pressure augments, the volume of the steam diminishes, so that the produce mP, that the equation contains, remains constant for such values of P as are very near to each other. We shall very shortly be witnesses of the fact, which will be explained in the calculation we shall make of the velocity of the engine at different pressure.

TABLE OF THE VOLUME OF THE STEAM GENERATED UNDER DIFFERENT PRESSURES.

Total Pressure expressed.		Corresponding temperature by Fahrenheit's thermometer.	Volume of the steam compared to the volume of the water that produced it.
In lbs. per square inch.	In atmospheres.		
lbs.		degrees.	
15	1.021	212.6	1,670
20	1.361	227.9	1,282
25	1.701	240.3	1,044
30	2.041	250.8	883
35	2.381	260.0	767
40	2.721	268.1	678
45	3.061	275.4	609
50	3.401	282.0	553
55	3.742	288.1	506
60	4.082	293.8	468
65	4.422	299.1	435
70	4.762	304.0	407
75	5.102	308.7	382
80	5.442	313.1	360
85	5.782	317.3	341
90	6.122	321.3	324
95	6.463	325.1	308
100	6.803	328.8	294

§ 12. *Of the combined Proportions that ought to be given to the parts of an Engine, in order that it may fulfil several conditions at the same time.*

We have given, above, separate from each other, the different practical formulæ of locomotion; but we may also combine those formulæ with one another. To give an example of this, and at the same time a practical application of the results obtained hitherto, we shall suppose that it is required to build an engine capable of drawing a certain given maximum load, and, at the same time, capable of attaining a certain speed, with another load also known.

In this case we may determine the diameter of the cylinder, according to the first condition; and the heating surface of the boiler according to the second. Letting, therefore, M′ be the given maximum load, M″ the second load mentioned above, and V″ the velocity of the engine corresponding with that second load, we shall have simultaneously the two following equations:—(See § 6 and 3.)

$$d = \sqrt{\frac{D\,(9\,M' + F)}{(P - \rho)\,l}}$$

and

$$S = \frac{V''\,[(9 \times M'' + F) + D\,\rho\,d^2\,l]}{(m\,P\,D)}$$

The first equation will give the diameter of the cylinder; and then, introduced in the second equation, it will fix the wanted value of S.

This case is evidently that of a railway on which it would be required that the average trains should have on a level a certain regular speed, and that, at the same time, the engines might ascend with those trains, and without any extra help, an acclivity occurring on a point of the road.

Let us then suppose that it is wanted to build an engine with coupled wheels, capable of drawing a train of 100 gross tons, at a speed of 20 miles an hour on a dead level; and that it is required, at the same time, that that engine be able to ascend without extra aid, and with the same load (reducing, however, its speed,) a plane inclined in the proportion of $\frac{1}{200}$.

We know that an engine working upon a level undergoes, from its load, a certain degree of resistance, which proceeds from the friction of the wagons; but in going up an inclined plane, the load presents not only that same friction of the wagons, but also a surplus of resistance proceeding from the tendency of the train to roll back towards the foot of the plane. The force that draws the train backwards, depends on the weight of the train and on the inclination of the plane. It is the gravity along the plane, and is equal to the mass that is to be moved, divided by the number that marks the inclination of the plane.

On an inclination of $\frac{1}{200}$, the gravity of a weight of 112 t., which is the weight of the train and engine together, is in pounds.

$$\frac{112 \times 2240}{200} = 1254 \text{ lbs.}$$

Now, 1254 lbs.. at the rate of 9 lbs. per ton (including the increase of friction in the engine,) represents the resistance of $\frac{1254}{9} = 139$ t. *on a dead level.* The surplus of resistance occasioned by the inclination of the plane is, therefore, equal to the traction of 139 t. on a level. Consequently, the *total* traction on the rising ground will be 139 t. + 100 t. = 239 t.

Thus, in this case, the load on the inclined plane will be - - - $M' = 239$ t. And the load on the dead level $M'' = 100$ t.

The engine being supposed to weigh 12 t., with coupled wheels, will have a friction of about 180 lbs. If, besides, we suppose it to have a wheel of 5 feet, with a stroke of 16 in. or 1.33 ft.; and if we wish the effective pressure $(P - \rho)$ in the boiler, during the ascent, not to exceed 60 lbs. per square inch, or, in other words, 8640 lbs. per *square foot*, the first equation will give, for the diameter of the cylinder—

$$d = \sqrt{\frac{5\,(9 \times 239 + 180)}{8640 \times 1.33}} = 1 \text{ foot.}$$

Thus the cylinder must have 1 ft. or 12 in. in diameter.

This value must be introduced in the second equation with the other data of the problem. Observing, moreover, that during the journey one may reduce the effective pressure in the boiler to 50 lbs. (or 65 lbs. total pressure) per square inch, which gives for the corresponding volume of the steam $m = 435$ (see the table given in the preceding paragraph,) the second equation will give—

$$S = 20 \times 5280\,\frac{(900+180)\,5 + 2117 \times 1 \times 1.33}{435 \times (65 \times 144) \times 5} = 42.65$$

By which we see that the effective evaporating power S of the engine must be 43 cubic feet of water per hour. And, as we know, by the experiments related above, that the effective power is equal to $\frac{3}{10}$ of the reduced heating surface, this surface must be $43 \times \frac{10}{9} = 143$ square feet.

Finally, this last condition will be fulfilled by giving, for instance, to the fireplace a heating surface of 50 square feet, and to the tubes a surface of 280 square feet.

This example indicates sufficiently the manner in which the calculation is to be made. It would be the same with any other combination that might occur. Evidently, nothing is required but to bring together the different equations concerning the different unknown quantities, and to express that they exist simultaneously.

ARTICLE VI.

PRACTICAL TABLES OF THE PROPORTIONS AND EFFECTS OF THE ENGINES.

§ 1. *A Practicable Table of the Diameter of the Cylinder and Pressure of Steam, necessary to enable a Locomotive Engine to draw a given Maximum Load.*

We have just calculated, in a special case, the diameter necessary for the cylinder of an engine working at a given pressure, so that it may draw a certain maximum load. In continuing the same calculation through a series of different cases, after the formula § 6, we form the following practical table, which will show either the diameter of the cylinder when the pressure is given, or the pressure in the boiler, when it is the diameter of the cylinder which is determined, or, finally, the maximum load when the two other *data* are fixed beforehand.

It must be understood that the engines will not be able to draw the loads marked in the table, unless the rails are in such a state as to offer a sufficient adhesion to the wheels; without which condition, the movement could not be effected, as will be explained in Chap. VIII.

A PRACTICAL TABLE OF THE DIAMETER OF THE CYLINDER AND PRESSURE OF STEAM CORRESPONDING TO GIVEN MAXIMUM LOADS.

DESCRIPTION OF THE ENGINE.	Max. load in gross tons tender includ.	Diameter of the Cylinder, in inches, the pressure per square inch in the Boiler being				
		50 lbs.	55 lbs.	60 lbs.	65 lbs.	70 lbs.
	tons.	in.	in.	in.	in.	in.
Engine with wheel - - 5 ft.	100	8.8	8.4	8.0	7.7	7.4
Stroke of the piston 16 in. or 1.33 ft.	125	9.7	9.2	8.8	8.5	8.2
	150	10.5	10.0	9.6	9.2	8.9
Weight - - - 8 tons.	175	11.3	10.8	10.3	9.9	9.5
or presumed friction - 120 lbs.	200	12.0	11.5	11.0	10.5	10.2
	225	12.7	12.1	11.6	11.1	10.7
	250	13.4	12.7	12.2	11.7	11.3
Engine with wheel - 5 ft.	200	12.2	11.6	11.1	10.7	10.3
Stroke of the piston, 16 in. or 1.33 ft.	225	12.9	12.3	11.8	11.3	10.9
	250	13.5	12.9	12.3	11.9	11.4
Weight, - - - 12 tons.	275	14.1	13.5	12.9	12.4	11.9
or presumed friction - 180 lbs.	300	14.7	14.0	13.4	12.9	12.4
	325	15.3	14.6	14.0	13.4	12.9
	350	15.8	15.1	14.4	13.9	13.4
Engine with wheel - - 5 ft.	200	11.5	10.9	10.5	10.0	9.7
Stroke of the piston 18 in. or 1.50 ft.	225	12.1	11.5	11.0	10.6	10.2
	250	12.7	12.1	11.6	11.1	10.7
Weight - - - 11 tons.	275	13.3	12.7	12.1	11.6	11.2
or presumed friction - 165 lbs.	300	13.8	13.2	12.6	12.1	11.7
	325	14.4	13.7	13.1	12.6	12.1
	350	14.9	14.2	13.6	13.0	12.6

§ 2. *A Practical Table of the length of Stroke of the Piston, and Diameter of Wheel, necessary to enable an Engine to draw a fixed Maximum Load at a given Pressure.*

In solving the formula § 7, in a series of cases adapted to the engines the most in use, the following table is formed, which will show, at first sight, either the length of stroke of the piston, or the diameter of the wheel which an engine ought to have, for it to draw a maximum load at a given pressure; or, again, the maximum loads corresponding to given dimensions for the length of stroke of the piston and diameter of the wheel.

A PRACTICAL TABLE OF THE LENGTH OF STROKE AND DIAMETER OF WHEEL, CORRESPONDING TO GIVEN MAXIMUM LOADS.

Description of the Engine.	Maximum load in gross tons, tender included.	Length of Stroke, in inches, the diameter of the wheel being			
		3 ft.	4 ft.	5 ft.	6 ft.
	tons.	in.	in.	in.	in.
Engine with cylinders 11 in. or 0.917 ft.	150	8.7	11.7	14.6	17.5
Weight - - - - - - - - 8 tons.	175	10.1	13.4	16.8	20.2
or presumed friction - 120 lbs.	200	11.4	15.2	19.0	22.8
Effective pressure per sq.	225	13.8	17.0	21.3	25.5
inch in the boiler - - 50 lbs.	250	14.1	18.8	23.5	28.2
Engine with cylinders 12 in. or 1 ft.	200	9.8	13.0	16.3	19.5
Weight - - - - - - - 10 tons.	225	10.9	14.5	18 1	21.8
or presumed friction - 150 lbs.	250	12.0	16.0	20.0	24.0
Effective pressure per sq.	275	13.1	17.5	21.9	26.3
inch in the boiler - - 50 lbs.	300	14.3	19.0	23.8	28.5
Engine with cylinders 13 in. or 1.083 ft	200	8.4	11.2	14.0	16.8
Weight - - - - - - - 11 tons.	225	9.3	12.5	15.6	18.7
or presumed friction - 165 lbs.	250	10.3	13.7	17.2	20.6
Effective pressure per sq.	275	11.3	15.0	18.8	22.5
inch in the boiler - - 50 lbs.	300	12.2	16.3	20.4	24.4
	325	13 2	17.6	22.0	26.4
	350	14.1	18.8	23.6	28.3
Engine with cylinders 14 in. or 1.166 ft.	250	8.9	11.9	14.9	17.9
Weight - - - - - - - 12 tons.	275	9.8	13.0	16.3	19.5
or presumed friction - 180 lbs.	300	10.6	14.1	17.7	21.2
Effective pressure per sq.	325	11.4	15.2	19.0	22.8
inch in the boiler - - 50 lbs.	350	12.3	16.3	20.4	24.5
	375	13.1	17.4	21.8	26.2
	400	13.9	18.5	23.2	27.8

§ 3. *A Practical Table of the Area of Heating Surface capable of producing a given Velocity with given Loads.*

In order to faciliate practical researches, we shall extend, to a certain number of the most ordinary cases, the calculation of the heating surface capable of producing predetermined effects.

The table which we are thus going to form after the formula in § 3, may serve, not only to determine the heating surface capable of producing desired effects, but also the velocity of given loads, when the heating surface is already determined.

The table supposes the engine working at 50 lbs. effective pressure, per square inch, in the boiler. As, however, the pressure has no perceptible influence on the velocity, as will be seen hereafter, if the engine works at a higher pressure, it will be able to attain a more considerable maximum load; but for all the loads of the table, it will, nevertheless, require the same heating surface in order to produce the same velocity. In consequence, the table may serve for any pressure, either above or below 50 lbs. The only difference will be in the maximum loads, which, agreeable to the pressure, will be greater or smaller than those fixed in the table.

By recurring to § 10 of the preceding Article, it will be seen in what manner the area of heating-surface is to be computed.

A PRACTICAL TABLE OF THE HEATING-SURFACES CAPABLE OF PRODUCING A GIVEN VELOCITY WITH GIVEN LOADS.

DESCRIPTION OF THE ENGINE.	Load in gross tons, tender included	Area of heating-surface of the boiler, in square feet the desired velocity in miles per hour being				
		10 miles.	15 miles.	20 miles.	25 miles.	30 miles.
Engine with wheel - - - - 5 ft.	tons.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
Stroke of the piston 16 in. or 1.33 ft.	25	36	54	71	89	107
Cylinders 11 inches, or - 0.917 ft.	50	46	68	91	113	136
Weight - - - - - - - - 8 tons.	75	55	83	110	138	165
or presumed friction - 120 lbs.	100	65	97	130	162	194
Effective presssure per sq.	125	75	112	149	186	223
inch in the boiler - - - 50 lbs.	150	84	126	168	210	252
	165	90	135	180	225	...
Engine with wheel - - - - 5 ft.	50	51	76	101	126	151
Stroke of the piston 16 in. or 1.33 ft.	75	60	90	120	150	180
Cylinders, 12 inches, or - - 1 ft.	100	70	105	140	175	210
Weight - - - - - - - 10 tons.	125	80	120	159	199	239
or presumed friction - - 150 lbs.	150	90	134	179	223	268
Effective pressure per sq.	175	99	149	198	248	297
inch in the boiler - - - 50 lbs.	196	107	161	215	268	...
Engine with wheel - - - - 5 ft.	50	56	83	111	138	166
Stroke of the piston 16 in. or 1.33 ft.	75	65	98	130	163	195
Cylinders 13 inches, or - - 1.083 ft.	100	75	112	150	187	224
Weight - - - - - - - 11 tons.	125	85	127	169	211	253
or presumed friction - - 165 lbs.	150	94	141	188	235	282
Effective pressure per sq.	175	104	156	208	260	...
inch in the boiler - - - 50 lbs.	200	114	171	227	284	...
	225	124	185	247	...	...
	231	126	189	251	...	...
Engine with wheel - - - - 5 ft.	50	61	91	121	151	181
Stroke of the piston 16 in. or 1.33 ft.	75	70	106	141	176	211
Cylinders 14 inches, or - - 1.166 ft.	100	80	120	160	200	240
Weight - - - - - - - 12 tons.	125	90	135	180	224	269
or presumed friction - - 180 lbs.	150	100	149	199	249	298
Effective pressure per sq.	175	109	164	218	273	...
inch in the boiler - - - 50 lbs.	200	119	178	238	297	...
	225	129	193	257	...	...
	250	139	208	277	...	...
	269	146	219	291	...	...
Engine with wheel - - - - 5 ft.	50	62	92	123	153	184
Stroke of the piston 18 in. or 1.50 ft.	75	71	107	142	178	213
Cylinders 12 inches, or - - 1 ft.	100	81	121	162	202	242
Weight - - - - - - - 11 tons.	125	91	136	181	226	271
or presumed friction - - 165 lbs.	150	100	151	201	251	301
Effective pressure per sq.	175	110	165	220	275	...
inch in the boiler - - - 50 lbs.	200	120	180	239	299	...
	221	128	192	256	...	...

4. § ***A practical Table of the Velocity of Engines with given Loads, and,*** vice versa, ***of the Load corresponding to a given Velocity.***

We have just given some examples of cases, in which it is wished to build an engine for a particalar end. The contrary case naturally presents itself afterwards. The question is, what effect may be expected from a given engine, that is to say, from an engine already constructed, and the dimensions of which can be measured.

In order to give here a practical and extensive application of the formulæ which resolve this question, we shall calculate, after the formula, § 1, a table of the velocity which engines, similar to those of Liverpool, viz. with 11 and 12 in. cylinders, will acquire with given loads. By that means, the experiments, which we are going to make on the Liverpool engines, will serve to verify, *by facts*, the accuracy of the formulæ, which we have deduced from principle.

As we think that this table, like the preceding ones, may be useful to practical men, in showing them the results, without obliging them to make the calculation, we shall extend it further to engines of different powers, such as are most in use on railways.

It will be remarked, that this table, giving the velocity corresponding to known loads, naturally furnishes also the loads of the engine, when, on the contrary, the velocity is given *a priori*. In like manner, as we have necessarily been obliged to confine ourselves, in each column, to the limit of load which the engine is capable of drawing at the pressure indicated, after the formula in § 4 ; so it follows that the same table gives equally the maximum loads for each pressure, as well as their correspond. ing velocity.

In the last column, the state of the regulator is indicated as follows : when it is entirely open, we write 1 ; when only half open, $\frac{1}{2}$; etc. This relates to the following tables, as well as to this one :

A PRACTICAL TABLE OF THE VELOCITY OF THE ENGINES WITH GIVEN LOADS, AND OF THE LOAD CORRESPONDING TO A GIVEN VELOCITY.

Description of the engine.	Load in gross tons tender included.	Velocity on a level in miles per hour, the effective pressure per sq. in. in the boiler being			State of the regulator.
		50 lbs.	55 lbs.	60 lbs.	
	tons.	miles.	miles.	miles.	
Engine with cylinders 11 in. or 0.917 ft.	25	40.07	40.38	40.60	1
Stroke of the piston 16 in., or 1.33 ft.	50	31.34	31.58	31.76	1
Wheel - - - - - - - - 5 ft.	75	25.74	25.93	26.06	1
Friction - - - - - - 110 lbs.	100	21.83	22.00	22.12	1
Area of heating surface 140 sq. ft.	125	18.96	19.10	19.21	1
Or effective evaporating	150	16.75	16.88	16.97	1
power per hour - - 42 cu. ft.	166	15.59	15.71	15.80	1
	175	...	15.12	15.21	1
	184	...	14.58	14.66	1
	202	...	...	13.67	1
Engine with cylinders 12 in., or 1 ft.	25	34.45	34.71	34.91	1
Stroke of the piston 16 in., or 1.33 ft.	50	27.80	28.01	28.16	1
Wheel - - - - - - - 5 ft.	75	23.29	23.47	23.60	1
Friction - - - - - - - 152 lbs.	150	20.05	20.21	20.32	1
Area of heating surface 140 sq. ft.	125	17.60	17.73	17.83	1
Or effective evaporating	150	15.58	15.80	15.89	1
power per hour - - 42 cu. ft.	175	14.14	14.25	14.33	1
	195	13.11	13.21	13.28	1
	200	...	12.98	13.05	1
	217	...	12.23	12.30	1
	255	...	...	10.91	1
Engine with cylinders 13 in., or 1.083 ft.	50	29.03	29.25	29.42	1
Stroke of the piston 16 in., or 1.33 ft.	75	24.68	24.86	25.00	1
Friction - - - - - - - 165 lbs.	100	21.46	21.62	21.74	1
Area of heating surface 160 sq. ft.	125	18.98	19.13	19.23	1
Or effective evaporating	150	17.02	17.15	17.24	1
power per hour - - 48 cu. ft.	175	15.42	15.54	15.63	1
	200	14.10	14.21	14.29	1
	225	12.99	13.09	13.16	1
	231	12.75	12.84	12.92	1
	256	...	11.92	11.99	1
	281	...	...	11.18	1
Engine with cylinders 14 in., or 1.166 ft.	50	29.83	30.06	30.22	1
Stroke of the piston 16 in., or 1.33 ft.	75	25.69	25.88	26.03	1
Friction - - - - - - - 180 lbs.	100	22.56	22.73	22.86	1
Area of heating surface 180 sq. ft.	125	20.11	20.26	20.37	1
Or effective evaporating	150	18.14	18.28	18.38	1
power per hour - - 54 cu. ft.	175	16.52	16.64	16.74	1
	200	15.17	15.28	15.37	1
	225	14.02	14.12	14.20	1
	250	13.03	13.13	13.20	1
	269	12.37	12.46	12.53	1
	298	...	11.57	11.63	1
	327	...	...	10.85	1
Engine with cylinders 12 in., or 1 ft.	50	26.16	26.36	26.51	1
Stroke of the piston 18 in., or 1.50 ft.	75	22.57	22.74	22.87	1
Friction - - - - - - - 165 lbs.	100	19.85	20.00	20.11	1
Area of heating surface 160 sq. ft.	125	17.71	17.85	17.95	1
Or effective evaporating	150	15.99	16.11	16.20	1
power per hour - - 48 cu. ft.	175	14.57	14.68	14.77	1
	200	13.39	13.49	13.56	1
	221	12.53	12.63	12.70	1
	246	...	11.73	11.80	1
	270	...	...	11.05	1

We remark here, as we have said above, that the whole influence of the pressure bears upon the limit of the load, but that its effect is almost insensible on the velocity. This result agrees with the principle ; for if the pressure required on the piston to move the load, be, for instance, 46 lbs. per square inch, is it not true that, provided the steam be abundantly furnished at that pressure, by the heating surface, it is of little consequence whether it be at first collected in the boiler at a pressure of 75 lbs. or 65 lbs. or at any other degree? Finally, at the moment of acting, it must any how be transformed into steam at 46 lbs. pressure, and the speed will depend solely on the quantity of steam at 46 lbs. that the boiler will have furnished. The small advantage we observe here in favor of a greater pressure is only owing to the fire being in that case naturally more intense ; a circumstance from which results, not that there is more water evaparated, but the same quantity, notwithstanding a higher pressure.

These tables show the effect that may be expected from an engine of given proportions, in regard either to the speed or to the load ; but it is understood that the effect can only be produced if the engine is put in a situation to apply all its power.

If, for instance, instead of the fire being sufficiently animated, it is left to languish, the quantity of water evaporated per minute will be diminished, and at the same time the effect of the engine.

If the engine, instead of being in good order, loses its steam, either by leaks in the boiler, or round the piston, or by the stuffing boxes, or elsewhere, it is clear that the effect must also be proportionately diminished.

If, by diminishing the opening of the regulator, we let only a portion of the generated steam penetrate into the cylinders, the boiler continuing at first to furnish the same quantity, more steam will necessarily be lost by the valves without acting on the pistons. Afterwards, as soon as the diminution of the steam thrown into the chimney has moderated the fire, there will be less steam generated, and that will consequently regulate the velocity. This is the case of all small loads drawn by the engines. The speed is never suffered to augment sufficiently to risk an accident by too rapid a motion of the piston or other parts of the mechanism. When the engine-men perceive that the train would run too fast, they diminish the aperture of the regulator, and make a moderate fire, in order to maintain a reasonable speed. In all the experiments we shall have occasion to relate below, we shall only once see, as we have already observed, the speed rise to 35 miles an hour, which is the greatest speed to which the engines have been hitherto submitted, excepting for a very short instant.

In the above tables, the limits of load of the engines, with the indicative pressure, are fixed by the necessity of the resistance on the piston not being greater than the force that must move it, as we have already said. With that maximum load, we see that an eleven-inch cylinder engine, working at 60 lbs. effective pressure, will still maintain a velocity of 13½ miles ; and a twelve-inch cylinder engine, with an effective pressure of 55 lbs., will still maintain a speed of 12 miles an hour. These velocities are those which will take place if the engine works in its right state ; that is to say, if the valve is fixed for a pressure of 60 lbs. or 55 lbs. But if it should happen that the valve be only regulated for a pressure of 50 lbs., and the pressure of 60 lbs. or 55 lbs. be produced by an extraordinary rising of the valve and by dint of losing steam, that is to say, only because the steam above 50 lbs. cannot escape as quickly as it is generated, then it is clear that although the evaporating power of the boiler remains the same, the effective part of that power will be considerably reduced, and, consequently, also the velocity. It is for that reason that, in the experiments, we shall see the speed go sometimes down to two or three miles an hour. But the state of the valve must then be observed. The elevated pressure will be seen to be produced only by an enormous loss of steam, and it will be easy, by the rising of the valve, to account for the diminution of speed.

In the cases of *maximum* load, it is evident that the steam will be spent by the cylinder, at the same pressure at which it has been generated in the boiler, and that the speed of the piston will be equal to the quickness with which the steam is generated. This fact has been proved in a gen-

ural manner in § 5 of the present article. It may be verified here by calculating the velocity with which the quantity of steam, generated in a minute, would cross the cylinders without any alteration or reduction of pressure. The velocity of the engine resulting from it, will be found to coincide exactly with that indicated in the table. This is a proof that, in case the engine only advances at that speed, the pressure in the cylinder is equal to that in the boiler.

Those cases of limit roads are those of which we have made use to determine the friction of the loaded engine, and we see here the principle justified, of which we then made use, viz. that in case the speed of these engines is under 12 miles an hour, the pressure in the cylinder is the same as in the boiler.

We have one observation more to make, which is, that in the engines there always exists a small loss, which we have not taken into account in our calculation; that is to say, the loss of the steam which, at each stroke of the piston, fills the passages that lead from the slides to the cylinders. It would be easy to take it into account, by the measures taken on each engine, of the diameter and length of these passages; but this loss is very insignificant, and would only complicate the calculation without any advantage.

ARTICLE VII.

CONFIRMATION OF THE ABOVE FORMULÆ BY EXPERIMENTS.

§ 1. *Experiments on the Velocity and Load of the Engines.*

As a verification of the formulæ we have laid down, and with a view to enable our readers to rest their calculations on material facts, we shall give here a series of experiments undertaken by us, in order to ascertain the speed with which the engines draw different loads at different degrees of pressure of the steam, in their daily and regular work.

These experiments were made on the Liverpool and Manchester Railway, the section of which, according to a levelling made in the month of August 1833, by Mr. Dixon, resident engineer, is as follows. We only give the part travelled over by the locomotive engines; there are, besides, under the city of Liverpool, three tunnels worked by separate stationary steam engines.

The railway, on leaving the station at Liverpool, until it terminates at Manchester, passes over the following distances and slopes:

Miles.			
0.53	dead level.		
5.23	descent - - -	at	$\frac{1}{1094}$
1.47	ascent - - -	at	$\frac{1}{96}$
1.87	dead level.		
1.39	descent - - -	at	$\frac{1}{880}$
2.41	descent - - -	at	$\frac{1}{2782}$
6.60	descent - - -	at	$\frac{1}{849}$
5.62	ascent - - -	at	$\frac{1}{1300}$
4.36	ascent - - -	at	$\frac{1}{1257}$
29.48	miles.		

From these different inclinations, we see that the same train presents various degrees of resistance, according to the part of the road travelled over, because the gravity of the total mass in motion becomes an alleviation in the descents, and an additional obstacle in the rising ground.

The result is, that a train of 100 t., offers on a dead level a resistance of 800 lbs.; besides the friction of the engine; and that the same train, if it is, for instance, drawn by an engine weighing 10 t., will, on arriving at an ascent of $\frac{1}{96}$, offer a resistance of 3,366 lbs., which upon a dead level would be equal to the resistance of a train of 421 t.

In fact, if we observe that a ton weighs 2,240 lbs., we shall find for the resistance:

100×8 lbs. = 800 lbs.; resistance owing to the friction.

$\frac{100 \times 2{,}240 \text{ lbs.}}{96}$ = 2,333 lbs. resistance owing to the gravity of the train, on a plane inclined at $\frac{1}{96}$.

$\frac{10 \times 2{,}240 \text{ lbs.}}{96}$ = 233 lbs. similar resistance owing to the gravity of the engine.

3,366 lbs. total resist-

ance, (not including the friction of the engine,) equal to that of a load of $\frac{3366}{8}$ = 421 t. on a level.

That is the manner in which we have calculated the real load of the engine on the different slopes it had to pass over during its journey.

The following column marks the pressure in the boiler, expressed first by the state of the balance, and then by its equivalent on the mercurial gauge. Thus, when the balance, fixed at 57, rose by the blowing to 58, we have written 57—58; and as for the ATLAS, for instance, that state of the balance corresponds with an effective pressure by the mercurial gauge of 61 lbs., we have written 57—58 = 61 lb.

We have also noted the state of the regulator; but we must add, that the handle of the regulator in these engines not turning on a graduated circle, as it would be better that it should, we have only been able to estimate the degree of opening of the regulator at sight and by approximation.

The speeds have been carefully taken down, by inscribing in minutes and quarters of minute the time when the engine passed before every quarter-mile stone of the road. These stones are numbered all along the way. At the same moment we noted the pressure in the boiler as marked on the valve balance.

The weight of the wagons was taken *exactly* in tons, cwts., quarters, and pounds. The tender cartwrights were not weighed, but they are reckoned at their average weight of 5½ t. when a fresh supply of water is taken in on the road, and 5 t. only in the contrary case.

We have marked the state of the weather, because it is a known fact that with the wind a-head, and still more with a side-wind that presses the flange of the wheels against the rails, the resistance of the train is augmented. Finally we have also mentioned the temperature of the water in the tender, in order that the reader may judge of the influence of that circumstance; and we have given the date of each of the experiments as a means of verification.

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
July 14, ATLAS, from Liverpool to Manchester,	level - - - - -	124	17.14	57...58 = 61	3/4	The engine was helped on the inclined plane at 1/96 by three engines with cylinders of 11 in. diameter.—Weather fair and calm.—Water cold in the tender.
in 1 h. 31′, - - with 25 wagons - - - 118.90 t.	descent 1/1094	90	21.17	57..... = 60	3/4	
delays 19′ - - tender - - - - - 5.50	descent 1/849	80	23.72	57...60 = 63	3/4	
	ascent 1/1300	154	18.75	57...59.5 = 62.5	3/4	
1 h. 50′ 124.40 t.	ascent 1/4257	133	17.89	57...58 = 61	3/4	
ATLAS { cylinder - - - 12 in.; stroke - - - - 16 in.; wheel - - - - 5 ft. { 6 wheels, 4 coupled; weight . - - - 11.40 t.; friction - - - 152 lbs.; heating surface { fire-box 57.06 sq. ft. tubes 217.88 sq. ft.						
July 16, ATLAS, from Liverpool to Manchester,	level - - - - -	105	15.00	50...52 = 54	3/4	The engine was helped on the inclined plane at 1/96 by two engines with 11 in. cylinders.—Weather fair and calm.—Water rather lukewarm in the tender.
in 1 h. 25′, - - - with 20 wagons - - - 99.25 t.	descent 1/1094	75	21.43	50...51 = 54	3/4	
delays 5′, tender - - - - - 5.50	descent 1/849	67	25.07	50...52 = 55	3/4	
	ascent 1/1300	129	22.64	50...51.25 = 54.25	1	
1 h. 30′ 104.75 t.	ascent 1/4257	112	19.63	50..... = 53	3/4	
July 17, ATLAS, from Liverpool to Manchester,	level - - - - -	71	20.00	50..... = 53	1/2	The engine was helped on the inclined plane at 1/96 by one engine with 11 in. cylinders.—The axle-box of one of the wagons too tight.—Weather fair and calm.—Water very hot in the tender.
in 1 h. 27′, - - - with 15 wagons - - - 65.4 t.	descent 1/1094	50	24.54	50...51 = 54	1/2	
delays 3′, tender - - - - - 5.5	descent 1/849	44	26.13	50..... = 53	1/2	
	ascent 1/1800	89	21.51	50...52 = 55	1/2	
1 h. 30′ 70.9 t.	ascent 1/4257	76	20.81	50..... = 53	1/2	

EXPERIMENTS ON THE VELOCITY AND LOAD OF THE ENGINES.

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator	Remarks.
1834.		tons.	miles.	lbs.		
July 17, ATLAS, from Manchester to Liverpool, in 1 h. 26′ - - - with 8 empty wagons	descent $\frac{1}{4257}$	26	26.47	50...51 = 54	$\frac{1}{3}$	The engine ascended, without help, the inclined plane at $\frac{1}{89}$. On the remainder of the way, the engine drew two wagons more.—Weather fair and calm.—Water very hot in the tender.
and 3 loaded - - - - 22.45 t.	descent $\frac{1}{1300}$	22	31.43	50...50.5 = 53.5	$\frac{1}{3}$	
delays 3′ tender - - - - - 5	ascent $\frac{1}{849}$	36	27.93	50...52 = 55	$\frac{1}{3}$	
1 h. 29′ 27.45 t.	ascent $\frac{1}{89}$	114	14.00	50...53 = 56	1	
July 23, ATLAS, from Liverpool, to Manchester in 3 h. 2′ - - - with 40 wagons - - 190 t.	level - - - - -	196	9 23	50...50.5 = 53.5	1	The engine was helped on the inclined plane at $\frac{1}{96}$ by four engines, three with 11 in. cylinders, and one with 14 in. cylinders —Weather fair and calm.—Water cold in the tender.
delays 15′ tender - - - - 5.5	descent $\frac{1}{1094}$	142	14.12	50..... = 53	1	
3 h. 17′ 195.5 t.	descent $\frac{1}{849}$	127	16.21	50..... = 53	1	
	ascent $\frac{1}{1300}$	240	8.00	50...51.75 = 55	1	
	ascent $\frac{1}{4257}$	209	5.87	50...51.5 = 54.5	1	
July 23, ATLAS, from Manchester to Liverpool, with 8 wagons - - - - - - 33.90 t.	ascent - $\frac{1}{89}$	199	6.00	50...52 = 55	1	Weather calm.
tender - - - - - - - - - - 5.50						
39.40 t.						
July 31, ATLAS, from Liverpool to Manchester, in 1 h. 44′ - - - with 14 wagons - - - 61.65 t.	level - - - - -	67	20.00	30..... = 33.5	1	The engine ascended the inclined plane at $\frac{1}{96}$ with its train in two trips. Weather fair and calm —In this experiment, the pressure was purposely varied. On the total delay, 26′ were employed in making an experiment.
delays 52′ tender - - - - - 5	descent $\frac{1}{1094}$	59	21.82	30..... = 33.5	1	
2 h. 36′ 66.65 t.	descent $\frac{1}{849}$	53	23.26	30...30.33 = 34	1	
	ascent $\frac{1}{1300}$	96	19.75	25...27.75 = 31	1	
	ascent $\frac{1}{4257}$	84	14.16	20...21.5 = 25.5	1	

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.		Remarks.
1834.		tons.	miles.		lbs.	
July 31, ATLAS, from Manchester to Liverpool,	level - - - - -	40	16.38	20...23	= 27.25	1 The engine ascended the inclined plane at $\frac{1}{89}$ without help.—Weather calm.
in 1 h. 54′ - - - with 8 wagons loaded	descent $\frac{1}{4257}$	37	19.53	20...20.5	= 25	1
and 4 empty - - - - 35.15 t.	descent $\frac{1}{1300}$	29	23.00	20...20.75	= 25.25	1 In this experiment, as in the former one, the pressure was lowered on purpose.
delay ... tender - - - - - 5	ascent $\frac{1}{849}$	57	16.08	20...20.75	= 25.25	1
	ascent $\frac{1}{89}$	202	7.50	45...47.5	= 51	1
1 h. 54′ 40.15 t.	ascent $\frac{1}{1094}$	53	15.79	20...20.25	= 24.75	1
Aug. 4, ATLAS, from Liverpool to Manchester,	level - - - - -	128	15.00	50.....	= 53	1 The engine was helped on the inclined plane at $\frac{1}{96}$ by two engines, one with 11 in. cylinders, and the other with 14 in. cylinders.—Weather fair and calm.—Water cold in the tender.
in 1 h. 58′ - - - with 25 wagons - - 122.64 t.	descent $\frac{1}{1094}$	92	17.14	50.....	= 53	1
delay ... tender - - - - 5	descent $\frac{1}{849}$	82	20.52	50.....	= 53	1
	ascent $\frac{1}{1300}$	158	15.38	50...50.5	= 535	1
1 h. 58′ 127.64 t.	ascent $\frac{1}{4257}$	137	15.24	50.....	= 53	1 We have seen in the experiments on the friction of the engines, that that day, ATLAS had a friction of 194 lbs. instead of 152 lbs.
Aug. 4, ATLAS, from Manchester to Liverpool, with 9 loaded wagons and 7 empty - - - - - 38.76 t. tender - - - - 5.50	ascent $\frac{1}{89}$	219	3.75	57...58.75	= 61.75	1 Weather fair and calm.
44.26 t.						
July 24, FURY, from Liverpool to Manchester,	level - - - - -	56	17.14	31...32	= 55	2 The engine ascended the inclined plane without help.—Weather fair and calm.—Water cold in the tender
in 1 h. 30′ - - - with 10 wagons - - - 51.16 t.	descent $\frac{1}{1094}$	40	18.00	31...32	= 55	2
delay ... tender - - - - 5	ascent $\frac{1}{96}$	244	6.31	32...35	= 65.5	1
	descent $\frac{1}{849}$	35	23.28	31...32	= 55	2
1 h. 30′ 56.16 t.	ascent $\frac{1}{1300}$	70	21.82	31...32.5	= 55.5	2
	ascent $\frac{1}{4257}$	60	21.17	31...32	= 55	2

EXPERIMENTS ON THE VELOCITY AND LOAD OF THE ENGINES.

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
FURY { cylinders - - - 11 in.; stroke - - - - - 16 in.; wheel - - - - - 5 ft.; weight - - - - 8.20 t.; friction - - - - 109 lbs.; heating surface { fire-box 32.87 sq. ft.; tubes 307.38 sq. ft.						
July 24, FURY, from Manchester to Liverpool,	level - - - - -	49	17.50	31...32 = 55	1	The engine ascended the inclined plane without help.—Weather fair, a sidewind blowing tolerably hard at intervals.—Water cold in the tender.
in 1 h. 35′ - - - with 10 wagons - - - 43.80 t.	descent $\frac{1}{4257}$	45	21.43	31...32 = 55	1	
delay ... tender - - - - 5	descent $\frac{1}{1300}$	36	22.00	31...32 = 55	1	
	ascent $\frac{1}{849}$	68	18.62	31...32 = 55	1	
1 h. 35′ 48.80 t.	ascent $\frac{1}{89}$	228	15.00	32...36 = 67	1	
	ascent $\frac{1}{1094}$	63	18.46	31...32 = 55	1	
Aug. 4, FURY, from Manchester to Liverpool,	level - - - - -	38	25.00	28...30 = 52.5	1	The engine went up the inclined plane without help.—Weather fair and calm.
in 1 h. 15′-- with 8 1st class coaches 32.97 t.	descent $\frac{1}{4257}$	35	25.71	28...31 = 54	1	
delays 9′ tender - - - 5	descent $\frac{1}{1300}$	28	26.94	28...30.25 = 53	1	
	ascent $\frac{1}{849}$	53	24.61	28...30 = 52.5	1	
1 h. 24′ 37.97 t.	ascent $\frac{1}{89}$	183	13.33	28...33 = 55	1	
	ascent $\frac{1}{1094}$	50	24.82	28...30 = 52.5	1	
Aug. 15, FURY, from Manchester to Liverpool,	level - - - - -	138	10.91	31...32.5 = 55.5	1	The engine only travelled that part of the road with this train. Its fire was in its greatest activity only towards the end of the journey. It had, besides, the impulse proceeding from the descent of the plane at $\frac{1}{96}$.—Weather fair.—Rails muddy.
with 28 wagons - - - 132.73 t.	ascent $\frac{1}{1094}$	176	13.33	31...32.5 = 55.5	1	
tender - - - - - 5.50						
138.23 t.						

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
July 26, FIREFLY, from Liverpool to Manchester,	level - - -	41	24.00	17... ... = 50	1	The engine was in bad order, and was going to be repaired. It was helped on the inclined plane at $\frac{1}{96}$ by another engine with 11 in. cylinders. Weather fair.—Water almost cold in the tender.
in 1 h. 35′ - with 8 1st class coaches 36.40 t.	descent $\frac{1}{849}$	25	25.45	15... ... = 45	1	
delays 5′ tender - - - - 5	ascent $\frac{1}{1300}$	52	21.29	15... ... = 45	1	
1 h. 40′ 41.40 t.	ascent $\frac{1}{4257}$	45	21.33	11... ... = 35	1	
FIREFLY { cylinders - - - 11 in.; stroke - - - - 18 in.; wheel - - - - - 5 ft.; weight - - - - 8.74 t.; friction - - - - 119 lbs.; heating surface { fire-box 43.91 sq. ft.; tubes 362.60 sq. ft.						
July 26, FIREFLY, from Manchester to Liverpool,	level - - -	41	25.71	17...18 = 50.33	½	The engine was in bad order. It was helped on the inclined plane at $\frac{1}{89}$ by an engine with 11 in. cylinders.—Weather rainy; wind tolerably strong against the direction of the engine.
in 1 h. 18′...with 8 1st class coaches 36.40 t.	descent $\frac{1}{4257}$	38	23.68	15.. ... = 45	½	
delay 5′ tender - - - - 5	descent $\frac{1}{1300}$	31	24.44	17...18 = 50.33	½	
1 h. 23′ 41.40 t.	ascent $\frac{1}{849}$	58	23.44	17...18.5 = 50.5	½	
	ascent $\frac{1}{1094}$	54	24.82	17.. ... = 50	½	
Aug. 1, VESTA, from Liverpool to Manchester,	level - - -	49	24.00	20...21.5 = 52	1	The engine ascended, without help, the inclined plane, at $\frac{1}{96}$, until about 60 yds. from the top. It was hauled up the remainder of the ascent.—Weather calm.—Water warm in the tender.
in 1 h. 22′ - - - with 10 wagons - - - 43.72 t.	descent $\frac{1}{1094}$	34	29.09	20...21 = 50	1	
delays 30′ tender - - - - 5	descent $\frac{1}{849}$	30	27.00	20...21 = 50	1	
1 h. 52′ 48.72 t.	ascent $\frac{1}{1300}$	61	23.56	20...21.5 = 52	1	
	ascent $\frac{1}{4257}$	52	25.71	20...21 = 50	1	The delay of 30 minutes on the road was occasioned by an experiment made on the engine.

EXPERIMENTS ON THE VELOCITY AND LOAD OF THE ENGINES.

Date of the Experiment and Designation of the engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
VESTA { cylinders - - - $11\frac{1}{8}$ in.; stroke - - - - - 16 in.; wheel - - - - - 5 ft.; weight - - - - 8.71 t.; friction - - - - 187 lbs.; heating surface { fire-box 46.00 sq. ft.; tubes 256.08 sq. ft.						
Aug. 1, VESTA, from Manchester to Liverpool,	level - - -	33	29.00	20...21 = 50	1	The engine ascended the inclined plane at $\frac{1}{89}$ without help.—Weather fair. Wind moderate, in favour of the motion.—Water very hot in the tender.
in 1 h. $5\frac{1}{2}'$ - - with 5 loaded wagons	descent $\frac{1}{4257}$	30	30.00	20...21 = 50	1	
and 5 empty - - - - 28.15 t.	descent $\frac{1}{1300}$	24	34.74	20...21 = 50	1	
delay ... tender - - - - 5	ascent $\frac{1}{849}$	47	28.93	20...21 = 50	1	
	ascent $\frac{1}{89}$	165	14.11	20..22.5 = 55	1	
1 h. $5\frac{1}{2}$ 33.15 t.	ascent $\frac{1}{1094}$	44	28.80	20...21 = 50	1	
Aug. 16, VESTA, from Manchester to Liverpool,	level - - -	94	15.00	20...21.5 = 52	1	The engine drew a part of its train on the inclined plane at $\frac{1}{89}$. The remainder was drawn by an additional engine.—Weather fair and calm. Water lukewarm in the tender. The delays that occurred in the journey were occasioned by several trials made with the engine.
in 1 h. 42′ with 20 wagons - - - 88.35 t.	descent $\frac{1}{4257}$	87	18.46	20...22 = 53.25	1	
delays 1 h. 10′ tender - - - 5.50	descent $\frac{1}{1300}$	71	24.00	20...22 = 53.25	1	
	ascent $\frac{1}{849}$	129	12.10	20...22.5 = 55	1	
2 h. 52′ 93.85 t.	ascent $\frac{1}{1094}$	121	18.75	20...21.5 = 52	1	
Aug. 16, VESTA, from Manchester to Liverpool, with 8 wagons - - - 31.75 t. tender - - - 5.50 37.45 t.	ascent $\frac{1}{89}$	183	3.25	20...23.5 = 58	1	Weather calm.—Water lukewarm in the tender.—These eight wagons were part of the train of the former experiment.

Date of the Experiment and Designation of the engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
Aug. 16, VESTA, from Manchester to Liverpool, with 8 loaded wagons and 4 empty - - - - 34.05 t. tender - - - - 5.00 — 39.05 t.	ascent $\frac{1}{89}$	189	3.00	20...23 = 56.5	1	Weather fair and calm.
Aug. 15, LEEDS, from Liverpool to Manchester,	level - - -	88	18.26	31...32.75 = 54.75	$\frac{3}{4}$	The engine was helped for the passage of the inclined plane at $\frac{1}{96}$ by an engine with 14 in. cylinders.—Weather calm.—Water rather less than lukewarm in the tender.
in. 1 h. 35′ - - with 20 wagons - - - 83.34 t.	descent $\frac{1}{1094}$	64	20.72	31...32 = 54	$\frac{3}{4}$	
delay ... tender - - - 5	descent $\frac{1}{849}$	57	24.00	31...32 = 54	$\frac{3}{4}$	
— —	ascent $\frac{1}{1300}$	109	20.34	31...32 = 54	$\frac{3}{4}$	
1 h. 55′ 88.34 t.	ascent $\frac{1}{4257}$	95	18.82	31...32 = 54	$\frac{3}{4}$	The regulator was not quite opened, because the engine is subject to prime, that is to say, to drive the water of the boiler into the cylinder with the steam.
LEEDS { cylinder - - - 11 in.						
LEEDS { stroke - - - - 16 in.						
LEEDS { wheel - - - - 5 ft.						
LEEDS { weight - - - - 7.07 t.						
LEEDS { friction - - 108 lbs.						
LEEDS { heating surface { fire-box 34.57 sq. ft.						
LEEDS { heating surface { tubes 307.38 sq. ft.						
Aug. 15, LEEDS, from Manchester to Liverpool,	descent $\frac{1}{4257}$	37	24.54	28...30 = 51.5	$\frac{3}{4}$	The engine ascended, without help, the inclined plane at $\frac{1}{89}$. Weather fair and calm.—Water very hot in the tender.
in 1 h. $17\frac{1}{2}$′ 1st half of the way { 8 wagons 34.38 t.	descent $\frac{1}{1300}$	30	30.00	25...27 = 46.5	$\frac{3}{4}$	
delay 3′ tender - - 5.50	ascent $\frac{1}{849}$	55	25.31	25...27 = 46.5	$\frac{3}{4}$	
— — 39.88 t.						
1 h. $20\frac{1}{2}$′ 2d half of the way { 7 wagons 29.65 t.	level - - -	35	22.50	25...27 = 46.5	$\frac{3}{4}$	
2d half of the way { tender - - 5.50	ascent $\frac{1}{89}$	168	10.00	28...29 = 48.5	1	
— 35.15 t.	ascent $\frac{1}{1094}$	46	25.71	28...32 = 54	$\frac{3}{4}$	

EXPERIMENTS ON THE VELOCITY AND LOAD OF THE ENGINES.

Date of the Experiment and Designation of the Engine and its load.	Inclination of the road.	Load of the engine reduced to a level.	Velocity in miles per hour.	Effective pressure in the boiler, in pounds per square inch, by the state of the Spring-balance.	State of the Regulator.	Remarks.
1834.		tons.	miles.	lbs.		
Aug. 15, LEEDS, from Liverpool to Manchester,	level - - -	38	21.81	25...28 = 47.5	3	The engine, while ascending, without help, the inclined plane at $\frac{1}{96}$ with its load, stopped near the top. It was hauled up the remainder of the ascent Weather fair and calm.—Water lukewarm in the tender.
in 1 h. 29′ - - with 7 wagons - - - 33.52 t.	descent $\frac{1}{1094}$	27	29.09	31...32 = 54	3	
delay 36′ tender - - - 5	descent $\frac{1}{849}$	23	28.96	25...28 = 47.5	3	
	ascent $\frac{1}{1300}$	48	21.43	15...16 = 29	3	
2 h. 5′ 38.52 t.	ascent $\frac{1}{4257}$	41	18.75	25...27 = 46.5	3	The delay that occurred on the road was occasioned by a trial made with the engine.
July 22, VULCAN, from Manchester to Liverpool, with 9 1st class coaches - - 34.07 t.					1	
tender - - 5	ascent $\frac{1}{89}$	188	11.42	31...36 = 57.5		Weather calm.—Water scarcely lukewarm in the tender on leaving Manchester.
34.07 t.						
VULCAN { cylinders - - - 11 in.						
stroke - - - - 16 in.						
wheel - - - - 5 ft.						
weight - - - - 8.34 t.						
friction - - - 136						
heating surface { fire-box 34.45 sq. ft.						
tubes 307.38 sq. ft. }						
July 22, VULCAN, from Liverpool to Manchester, with 9 1st class coaches - - 36.32 t.	ascent $\frac{1}{96}$	186	18.75	31...36 = 57.5	1	Weather fair.—A very slight wind against the motion of the engine.—Water cold in the tender.
tender - - 5						
41.32 t.						

These experiments show better than any possible reasonings, what may be expected of locomotive engines in a daily work. That is the reason why we have joined them all together in this place.

Their coincidence with the table of velocities, deduced from calculation, will be remarked.

§ 2. *Of the Velocity of the Maximum useful Effect.*

We have seen above (Chap. V. Art. V. § 2) that the load an engine is able to draw, at a given speed, is expressed by

$$M = \frac{m\,SPD - \rho\, d^2\, lV}{(\delta + n)\,V\,D} - \frac{F}{\delta + n}.$$

If we multiply the two members of this equation by V, we have

$$MV = \frac{m\,S\,P\,D - \rho\, d^2\, l\,V}{(\delta + n)\,D} - \frac{F\,V}{\delta + n}.$$

The produce MV, of the load multiplied by the velocity with which that load is drawn, represents the *useful effect* produced by the engine in the unit of time. We see consequently, here, that that useful effect will be so much the greater as the speed is less; for in the second member that speed only appears in the negative terms. As, on the other hand, the engine cannot without considerable loss of steam, move at a velocity less than that which corresponds to the quickness with which the steam is generated in the boiler, it follows that the *maximum* of useful effect will take place at that speed.

By examining the above table, under the same point of view, we ascertain by experience what has already been proved by calculation, viz., that the greatest useful effect is produced at the least velocity.

Let us take, for instance, an engine with an eleven-inch cylinder, working 10 hours a-day. At its greatest speed, of 30 miles an hour, it will be able, with an effective pressure of 50 lbs. per square inch in the boiler, to draw 50 t.; and at its least speed, with an equal pressure in the boiler, it will draw 160 t.

By drawing trains of 50 t. at a velocity of 30 miles an hour, it will, in its 10 hours' work, have drawn 50 t. to a distance of 300 miles, or, in other words,

15,000 t. to the distance of one mile.

By drawing trains of 160 t. at a speed of 15.5 miles an hour, it will, in the same space of time, have taken 160 t. to a distance of 155 miles, which is equal to

24,800 t. to the distance of one mile.

There is, consequently, a considerable advantage to be reaped, in making the engines, if possible, work with the greatest loads, which correspond with the least speeds. It must be remarked, that the difference between the two effects would have been still greater, if from each load we had deducted the tender, as making, in regard to the useful effect, a part of the engine, and not of the train.

It is scarcely necessary to add, that when the speed becomes the express condition of the haulage, as, for instance, in respect to passengers, these considerations are no longer applicable. We speak here only theoretically.

The difference we have found in the useful effect produced, is owing to the circumstance that in the two cases the resistance proper to the engine remained nearly the same, while in the first case it had to be moved 300 miles, and in the second only 155 miles. The same is true in regard to the atmospheric pressure, which forms a part of the resistance on the piston. The engine having travelled in one circumstance double the distance of the other, was naturally obliged to give a double number of strokes of the piston; and as at each of these strokes of the piston the atmospheric pressure must be overcome, we see that the expense of moving power necessary to conquer the resistance of the atmosphere is in the proportion of the numbers 300 and 155; that is to say, that that force, as well as the force required to move the engine, is in proportion to the velocity of the motion. This is a further proof that, in calculating the effect of these engines, one cannot, as is usually the case, neglect, in all circumstances, the atmospheric pressure; and that it is only in those cases in which the speed is not taken into account that that simplification can take place without mistake.

If we sometimes find calculations of the power of locomotive engines, or any other sort of steam engines, in which there appears what is termed *lost power;* that is to say, calculations according to which it would appear that these engines produce in practice only one-third or even a quarter of what